

BEHAVIOR MONOGRAPHS

Volume 4; Number 4, 1922

Serial Number 20

Edited by
WALTER S. HUNTER
University of Kansas

Visual Perception of the Chick

BY

HAROLD C. BINGHAM

A dissertation submitted to the Board
of University Studies of the Johns Hop-
kins University in conformity with the
requirements for the degree of Doctor
of Philosophy.

Published by
WILLIAMS & WILKINS COMPANY
Mount Royal and Guilford Avenues
Baltimore, U. S. A.

1922

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PREFACE

The observations on which the experimental portion of the following pages is based were made upon four different groups of Plymouth Rock chicks. Work with the first three groups was conducted in the Harvard Psychological Laboratory during 1911-1912 when the visual factors in space perception described in Chapters V and VI were studied. The data on flicker perception reported in Chapter VII and the greater portion of the material on problem learning, presented in Chapter VIII, were gathered in the same laboratory during 1915-1916. The results on relativity and specificity of reactions reported in Chapter IX were obtained quite incidentally during the two years of research.

In this Monograph there is presented an account of the results as written in 1916. A preliminary report had been published in 1913 in the *Journal of Animal Behavior*, following which there were several published comments relative to certain questions raised in the paper. Cognizance of these discussions and the related literature was taken at the time the manuscript was prepared. Rather than isolate the unpublished portion, it now seems advisable to present the entire study in the form it had taken before the United States became a participant in The World War. A revision of the manuscript to make it strictly current is not deemed worth while.

The problem in spatial perception was proposed by Professor Robert M. Yerkes, under whose guidance the entire study was made. During the year preceding my initial work on this problem, he completed in the Harvard Psychological Laboratory the construction of the apparatus which has been described in a Monograph¹ on "Methods of studying vision in animals." For the use of this apparatus, for his numerous suggestions in method, for his precise formulation of problems, and above all for his continued and sympathetic encouragement, I wish to

¹ *Behavior Monographs*, Vol. 1, No. 2.

express sincere appreciation. My only contribution to the apparatus is the simple mechanism described in Chapter VII, yet in the development of this device his helpful suggestions always were at my command. Likewise, my only contribution to the main problem of visual perception in the chick is that represented by the preliminary data on the reactions to flicker stimuli. Gladly I acknowledge my indebtedness to Professor Yerkes for his patience in starting me on this experimental task and for his kindly interest throughout the study.

This opportunity is also taken to express my obligations to Miss Doris M. Wood, who generously read the entire manuscript, and to my wife, who assisted in various ways with the preparation of the manuscript.

HAROLD C. BINGHAM.

Washington, D. C., January 25, 1922.

PART I. HISTORICAL

CHAPTER I

ORIGIN AND HISTORY OF THE DOMESTIC FOWL

In the jungles of southern Asia lives a species of birds known, from the nature of its habitat, as the Jungle Fowl. As the name suggests, it is a wild type of *Gallus*, the comb fowl, to which our domestic chick belongs. Several varieties of these little wild fowls are to be found in India and the Malay regions, but all have general characteristics in common. Four groups are generally recognized, namely, the Bankiva Fowl, the Sonnerat Fowl, the Ceylon Jungle Fowl, and the Fork-tailed Jungle Fowl or Gangegar. These jungle fowls are commonly regarded as the ancestors of all the present breeds of domestic fowl.

Gallus bankiva, the wild type which seems to be most closely related to our domestic fowl, is found throughout India, in the Malay Islands, and in the Philippines. It closely resembles the domestic Black-Red Game Bantam. The feathers of the head and neck, including the long hanging feathers at the back of the head, possess a glistening golden hue. The golden hue of the collar is matched with the long supra-tail feathers, but the shorter straight tail feathers beneath are all black. The middle feathers of the wings are a lively brown, the remainder, in the male, being dark gray with pale borders. The iris is orange red, the head dress red, the bill brown, and the foot slate black. The body length reaches 56 cm., the wing length 22 cm., and the tail length 27 cm.

The tail of the smaller female stands more erect, her comb and wattles are barely noticeable, and her long neck feathers—black with yellowish borders—add brownish black spots to the mantle plumage. The dorsal side is cream colored. The tail and supra-tail feathers are a brownish black.

Gallus sonnerati was the first of the wild breeds to become known. It occurs in west, south, and central India. The long slender feathers on the head, neck, and upper back of the male

are black with gray edges and white tips; near the end they bear an ornamental yellowish spot. The other feathers of the dorsal side are narrowly striped with white. The ventral side of the body is black, dotted with little white lines, and becomes almost white at the median line.

Domestication of the Sonnerat Fowl is more difficult than that of Bankiva. We are told that these two wild species will cross but the hybrids are said to be sterile. The sterility of the hybrids and the characteristic differences between tamed Bankiva and Sonnerat fowls have frequently been urged as evidence that the latter is not the ancestor of our domestic chick.

The Ceylon Jungle Fowl, *Gallus lafayetti*, closely resembles Bankiva. The male is distinguished from Bankiva by the orange-red breast, the long black-striped yellow neck feathers, and the glistening blue-black throat and supra-tail feathers. The slightly notched red comb, bearing on the lower part a large oval yellow spot, is also distinctive. The Ceylon and Bankiva females differ with respect to voice. According to a report of the National Poultry Conference, Reading, England, (cited by Houwink), Lafayetti has been crossed with common fowls and fertile hybrids were obtained.

The extreme shyness of the Fork-tailed Gangegar, *Gallus varius*, is a characteristic phase of its behavior indicating that it would not be readily domesticated. At the least noise, it hides in the alang-alang thickets, which makes close observation of this fowl in its natural habitat very difficult. Were it not for the male's noisy voice it would scarcely be noticed. Early morning is the best time to observe it, for it then leaves the thickets for the open places in search of food.

Gangegar seems to be very remotely related to the three preceding classes. It differs from them in the number of supra-tail feathers, the untoothed comb, and single neck lobe. It also has certain characteristic differences in coloring.

Of these four groups of wild fowl, Bankiva is most generally regarded as the ancestor of the common chick. Darwin, basing his conclusions chiefly upon structural evidence, is inclined to regard Bankiva as the original stock. "Having kept," he says, "nearly all the English breeds of the fowl alive, having bred and crossed them and examined their skeletons, it appears to me almost certain that all are the descendants of the wild Indian

fowl, *Gallus bankiva*." Others think that the jungle and domestic fowls sprang from a common ancestor of intermediate size which has since become extinct, but Houwink thinks it is improbable that the domestic fowl has an extinct ancestor, for it, like the known wild poultry races which have maintained themselves in the midst of the oldest and most populous Indian towns, surely have been preserved somewhere in Central Asia.

The behavior of *Bankiva*, as reported by certain naturalistic observers, would lead one to regard it as the most probable ancestor of the domestic fowl. Guillemard is cited in Brehm's *Tierleben* to the effect that captive *Bankiva* fowls on the island of Sulu are very tame and are easily crossed with domestic fowls. In the same source, but in a different citation, it is asserted that in the mountainous regions of Pegu, where the *Bankiva* abound, they come into the villages and yards of the natives where they mix with the tame fowls. Another citation has it that crossing with the domestic chick is a common occurrence in Ceylon and that the male hybrids resulting are far more spirited and have sharper spurs than the parent males.

At the present time there are domestic fowls which are very similar in structure to the wild *Bankiva*. It has been found that modifications in food and environment may cause changes in the general form and color of poultry, if we may believe Houwink on this point. It is rather resonable that the breeds resembling *Bankiva* have descended from that origin. Natural and scientific selection might readily account for the variations and further development that have resulted.

From discoveries in mounds and other ancient settlements of man, it appears that the chick has long been domesticated. Along with the duck and the goose, the chick could have been taken and held in captivity with comparative ease. On this fact is based the assumption that the origin of the fowl's history dates back to ancient times. Robinson deems it quite probable that it was domesticated before any of the mammals. Houwink on the contrary, reasons that it was not kept by man until population took on a permanent aspect. Unlike the dog, its domestication would have been neglected by the hunter. Such animals as the cow and the horse would naturally be first tamed by the nomads.

Turning to evidences which ancient literature furnishes, the

first reference to the domestic fowl is probably made in the great Chinese Encyclopedia which was prepared about the fourteenth or fifteenth century before Christ. This book suggests that the chick was brought from the West and from India into China. This would indicate that it is an old domestic animal with the Chinese and Japanese. It is possible, of course, that this account is based upon nothing more reliable than tradition.

The Egyptians are also said to have had domestic chickens at an early date. It is thought that they were received from the Orient. It is probable that the fowls were transported from Egypt or Persia to southern Europe, Greece, and Rome. The chick is not mentioned by the Old Testament, Homer, and Hesiod, but it was to be found in Babylonia as early as the seventh and sixth centuries before Christ. It was surely known to the Greeks as early as the fifth century before Christ, for Socrates, after taking the poison which caused his death, reminds Crito that he owes a cock to Asclepius and asks him to pay the debt. Darwin is of the opinion that the domestic fowl appeared in Europe about 600 B.C.

The early history of the chick is thus quite uncertain, despite the fact that a number of students have given it their attention. Numerous theories have been advanced, evidence more or less convincing has been submitted in favor of them, yet the available facts are not conclusive. The evidence thus far furnished does little more than provide a basis for theories, and in consequence the statements which occur in the literature must be accepted with caution. For the most part it seems probable that *Gallus bankiva* is the common ancestor of the numerous breeds of domestic chicks which we now possess. It is quite reasonable to conclude that man caught the wild fowl, domesticated and developed it for cock fighting, fortune telling, or domestic use according to his peculiar interests. Chickens used for fighting tended to remain fighters; those accustomed to domestic life tended to retain their utilitarian characteristics; and from some of the deviations which have occasionally occurred the numerous breeds which we possess today have been developed.

Thus the wild fowl, after its domestication, has been permanently adopted by man. In a general way, its distribution over the earth seems to have followed the migrations of the

Aryan peoples. The Chinese record, however, if its reliability be not questioned, suggests an important exception. At any rate, the life of the chick has been so long connected with human activities that it has become quite dependent upon man. If left to itself, it is no longer able to maintain an existence. Since becoming domesticated, it has changed in form and has been bred toward gigantic or dwarfish structure according to climatic conditions and the influence of natural and artificial selection.

As a result of these variations, there were in the year 1911 over 160 breeds of domestic fowl. Five of these are recognized as distinctly American breeds, of which the most typical is the Barred Plymouth Rock. An accurate knowledge of the Plymouth Rock's blood heritage is impossible, for in the duplication of the original stocks and in the perfection of the breed numerous elements were intermingled. It is generally believed that the original stock was secured by crossing the American Dominique with black Javas or Cochins. Light Brahma, Dark Brahma, and Pit Game are said to have been used in its making. This breed was briefly known as Plymouth Rock until the white variety appeared, after which it became known as Barred Plymouth Rock.

This particular type of fowl appeared about the middle of the 19th century. Some of the more intelligent poultry breeders conceived the idea of a breed of chicks particularly adapted to American conditions. Accordingly, they set about developing birds with the desired characteristics. As a result of this activity there were exhibited in 1869 the first Plymouth Rocks. These birds were so favorably received that they soon became more numerous in America than all the other standard bred birds combined. The observations reported in Part II were made upon this strain of chick.

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CHAPTER II

EXPERIMENTAL LITERATURE ON VISION IN THE CHICK

During the course of the investigation which is reported in Part II, the question was asked by a Harvard undergraduate: Why is it that a chicken always wants to get on the other side of the road when it sees an automobile? The question has nothing in common with my investigation but it is suggestive of a prevalent notion regarding the stupidity of the domestic fowl. The chick seems to rank low in intelligence according to unscientific observers. Eulogistic literature, in which anecdotes and remarkable stories abound, often contains accounts of exceptional and almost incredible behavior of dogs, cats, horses, parrots and the like, but in such collections of stories and incidents, it is noteworthy that the chick has been generally neglected.

One may incidentally hear of such stories as that of a hen finding her way through an open window to a bedroom in a farm house and selecting the top of the old-fashioned bureau on which to make a nest. In her efforts to collect all of the articles that might be used in a hen's nest, she knocked from the bureau a kerosene lamp and made use of a doily on which the lamp had been standing. In this extraordinary nest, composed of pin-cushions, ribbons, laces, doilies, and handkerchiefs, she laid an egg.

The above anecdote was related to me by people who personally observed "biddy's stolen nest" and the results. Though trivial to the extent of absurdity in science, it is nevertheless typical of much that one may read about cats and dogs in the eulogies of the anecdotists. Chicken anecdotes of this sort seldom appear in print, but let one cat claw at the knob of a door supposedly as a signal to be let out, and she becomes (see Thorndike (30)) "the representative of the cat-mind in all the books." It seems that no chicken has performed any act which might furnish the aspiring eulogist with a representation of the chick-mind.

Considering the apparent delight of the naturalists and semi-experimentalists in repeating animal stories of an exceptional

type, it is rather surprising that so little chick behavior has found its way into print. Apparently the animal anecdotists saw in the behavior of the chicken only acts of *stupidity*, rather than *intelligence*, and as a result of their eulogistic inclinations they neglected to report such facts. The chick does not fill the place of a household pet; hence the stock of chick stories like that related above has generally been unknown to the reporters of animal anecdotes.

Despite the tendency of Aristotle to report unusual facts about animals, he has said very little about the chick. The brief description of it is typical of his usual method of describing animal behavior. He naively says:

Young hens are the first to lay, and they do so at the beginning of spring and lay more eggs than the older hens, but the eggs of the younger hens are comparatively small. As a general rule, if hens get no brooding they pine and sicken. After copulation hens shiver and shake themselves, and often kick rubbish about all around them—and this, by the way, they do sometimes after laying. . . . (1).

With such generalization, Aristotle's description of chick behavior ends. His metaphysical interests did not encourage intensive observations that would lead to a description of the fowl's perceptions.

Offering little or nothing for the pure naturalists to eulogize, therefore, chick behavior is not reported until the scientific spirit spreads to the field of animal behavior. Naturally, then, the first publications involving the chick are those of the semi-experimentalists. Stimulated, as they must have been, by the theory of natural selection, one might well expect these first observations to be turned upon the instincts. From a consideration of inherited types of behavior, it is a logical step to individual modifiability. And the investigation of habit formation, involving the sensory equipment of the organism, finally leads to studies of perceptual discrimination.

Early reference to the chick's vision is incidentally made by Spaulding (28), representing the semi-experimental group, whose observations were primarily centered upon the nature of the pecking and drinking reactions. In a general way, Preyer (25) observes that the perfection of sight in newly hatched fowls is astonishing when compared with the imperfection of this sense in newly born humans. The work of Romanes (26),

Eimer (8), Mills (22), and Morgan (23) also primarily involves the instincts. There is a tendency for this transitional group to become controversial over the problem of instinct and acquisition. No definite experimental data are produced to settle the disputed questions. Mills loosely reports some of his observations in diary form. The diary method also appears a few years later in reports by Hunt (12) and Kline (19) in each of which certain visual discriminative ability is described.

Irritated by the controversies of this transition group and the failure to answer on empirical grounds the disputed questions, Thorndike (30) sets out on a procedure distinctively experimental. However, he barely touches the problem of visual acuity in the chick and, for the most part, his observations are confined to crude studies of the chick's space and color perceptions.

Nearly ten years later, Hess (9-11) takes up the problem of the chick's color vision as well as light and dark adaptation. The method of Hess involves for the first time the use of the dark room for studying visual acuity in the chick. Although he greatly improves on the method of Thorndike and deserves praise for introducing the controllable method of the dark room which has later been highly refined, Hess nevertheless often leaves the reader uncertain of the experimental conditions. He should be credited with ingenuity and alertness, but his method in certain details is too crude for the problems with which he deals.

A study, certainly deserving more severe criticism than the work of Hess, has been jointly reported by Katz and Révész (18). These authors have hastily considered a variety of topics relative to the chick's visual discriminative ability. Their crude "Klebmethode" has been applied to several phases of the problem, including the topics of size and form perception as well as color discrimination in "unsuppressed daylight."

In its simpler form, the "Klebmethode" of Katz and Révész consists in pasting on a cardboard kernels of grain at which the chick's pecking response is to become inhibited. Among these "glued" kernels is scattered a different kind of grain which the bird is allowed to pick up. To illustrate, it was found by the experimenters that the chicks preferred rice to wheat. The bird was classed as "Fehlerfrei" when it had picked up the loose

wheat without pecking at the glued rice. The observers had two quantitative measurements for the rapidity of learning: (1) The number of series necessary for a perfect habit; (2) the number of reactions to rice. To make sure that the errorless chicks did not avoid the rice by means of the glue which might be visible on the pasted kernels, the rice was scattered loosely upon the cardboard in the same manner as the wheat. The wheat was again eaten by the errorless chicks and the rice was left. The discrimination, the authors concluded, was between wheat and rice.

Having found that the chick could pick up wheat and avoid rice, Katz and Révész sought an answer to the question: By what means does the chick discriminate the grains? Accordingly they turned to a study of size and form discrimination. Because the chicks could be trained to eat only half grains of rice when scattered among whole grains, the authors were convinced that there was discrimination of size and form. Further observation leads them to conclude that the chick discriminates squares and triangles. They say:

Knowledge of this fact we secured through a variation of the experimental procedure. Out of green peas (some of which had been readily eaten), we cut three and four cornered pieces. On account of their moisture, they could not be glued down, so we laid the four sided pieces upon a glass plate and the three sided pieces under it. The chick found that the three sided pieces could not be reached and soon ceased to peck at them. Then if we laid both forms upon the glass plate, only the squares were picked up. By means of the same method we found that the chick discriminates between triangles and circles as well as squares and triangles.

The report of Katz and Révész leaves the reader too often uncertain of the experimental conditions. They have tried to do too much and have not treated any one task intensively. Their report indicates carelessness and indifference to details. No doubt the assertion that the chick discriminates squares and triangles as well as triangles and circles is true for the conditions under which the experiment was made. But from the written account, one cannot tell what the conditions were. One does not know, for example, the relative sizes of the different forms. Were they equal in area? Was the square an inscription or a circumscription of the circle? Was the diameter of the circle equal to the side of the square or the altitude of the triangle?

Was the third dimension constant? These are some of the factors which must be known before one can safely say that the chick perceives form. One could truthfully state that an animal discriminates between a circle and a triangle if it regularly chooses the former even though the triangle be twice as large as the circle, but it is improbable that the basis of discrimination in such a case would be anything other than size. Since such points are ignored in the report by Katz and Révész, one suspects of the experimenters carelessness in technique.

Furthermore, no information is offered as to the method of cutting these forms. It is a difficult matter to cut green peas with regularity. Can we be certain that the chicks discriminated on the basis of form rather than irregularity of surface? No mention is made of controls to eliminate this possibility. Because the authors leave vital points like these unmentioned and apparently unnoticed, one is inclined to regard the experiment as quite superficial.

A definite answer to the controversy of the semi-experimental school over the nature of the chick's instinctive reactions is offered for the first time by Breed (4).¹ His study of the instincts is supplemented by his study of certain habits, out of which grew the problem of accurately determining the nature of the color, form, and size stimuli in response to which a chick is able to acquire a habit of reaction (5). The chief significance of Breed's later study appears in his contribution to the development of the dark-room method. For testing the chick's perception of colors, Breed combines the Yerkes discrimination method (34) with the Hess (9-11) dark-room method. The next step is the adaptation of the combined methods to investigations of size and form perception. The stimuli were presented to the chicks by means of the illumination of two plates of opal flashed glass over which were set mats of tin or cardboard containing the desired openings. Thus the chick was given an opportunity of selecting a circle when appearing with a square, or of discriminating a larger from a smaller stimulus.

¹Certain instincts have later been carefully observed by Pearl (24). The instincts considered relate primarily to behavior having practical significance for the poultry keeper. In the single reference cited at the close of this chapter, there appears a selected bibliography referring to a number of other papers on related subjects.

For testing size discrimination, two circular areas—one 5 cm. in diameter, the other 8 cm.—were presented to the chick. Evidence of a perfect habit appeared at approximately two hundred trials. Controls were introduced throughout the training to eliminate “difference in brightness of the lighted areas” and “difference in brightness of the right and left sides of the experiment box.” In spite of ambiguity in the use of “brightness” Breed’s conception is fairly obvious.

In the study of form perception, Breed used three chicks, one of which, he declares, “learned to discriminate two optical stimuli on the basis of difference of form.” The forms were a circle and a square equal in area. Because his studies of the reactions of other chicks to similar stimuli yielded negative results, he attributes the positive reactions of this particular chick to fortune in the choice of animal. In this connection, it is significant that the chick was credited with a perfect record in the fifth training series or after only forty trials. A perfect habit is clearly evident after one hundred trials. For space stimuli differing in form alone this rate of habit formation appears, in the light of later results, unusually rapid and suggests that the successful chick may have discovered some easy cue other than the form difference. This possibility suggests itself rather forcefully when one considers that Breed was using a mechanism only partially standardized; it rises to the level of probability when one notes that he does not report controls for varying the relative positions of the stimuli within the sliding frame.²

It is unfortunate that Breed also failed to make control tests to determine whether the distribution of light on the chick’s retina was the basis of discrimination. Such a control is easily made in the case of a triangle by inverting the stimulus. The inversion of a square would cause no change in the distribution of light, but such a change might be produced by turning the square through 45 degrees. Even had there been no possibility of an unsuspected cue furnishing the chick with a discriminable factor, there remained this second possibility which Breed did not consider.

² A discussion of controls in which this possibility was found to be a reality appears in the *Journal of Animal Behavior*, 1913, vol. 3, pp. 86–90.

A study of the relation of strength of stimulus to rate of learning in the chick, though subsequent to Breed's work, is reported by Cole (7) prior to Breed's account (5) of his dark room work. Cole presented brightness stimuli to his chicks, using the same apparatus as Breed.

A further stage in the development of the combined "dark-room-discrimination" method is indicated in a joint report by Yerkes and Watson (35), on methods of studying vision. They have greatly refined the apparatus used by Breed and Cole and limited its use to studying *light* vision. In addition, they have developed a special apparatus for studying color vision.

The first use of the Yerkes light vision apparatus with chicks is my study of size and form perception (2). The aim of this study was to locate thresholds for standardized forms and sizes. With a standard circle 6 cm. in diameter, the threshold was found to be one-fourth to one-sixth. But instead of determining a limit in form perception, the question became chiefly whether the chick perceives forms. It was found that the chick could discriminate between a circle and an upright triangle of equal area, but the evidence of discrimination disappeared when the triangle was inverted. Since Breed failed to make a similar control, his statement that one chick "learned to discriminate two optical stimuli on the basis of form" may be questioned. A safer conclusion seems to be that the chick reacts to unequal stimulation of different parts of the retina.

With reference to this interpretation of the reactions to form stimuli, Watson (33) says:

Bingham has raised the whole question as to what is meant by form.³ While the chick can apparently respond to the difference in form between the circle and the square, and the circle and the triangle, when they are equal in area, yet such responses, after all, are really nothing more than keen perception of size differences. He draws this conclusion from the fact that after the chick has learned the circle-triangle habit with the base of the triangle down, the habit will disintegrate if the apex is placed down. (p. 366).

Quite naturally, this interpretation of form perception has called forth considerable comment. Hunter's contribution (13)

³ For this suggestion I hasten to acknowledge my indebtedness to Professor Yerkes who proposed this question as a part of my experimental task. Because he conceived the possibility, however, it does not follow that he agrees with my view. All responsibility for subsequent use of the conception as an explanation of the facts, I alone assume.

to the discussion which has ensued consists in calling attention to the need of sharper distinction between the study of form discrimination and pattern discrimination. He argues that we should not expect the child to discriminate forms in the sense of my definition. He theorizes that infrahuman animals "have only a more or less crude pattern vision." As a means of testing the validity of his theory he proposes that the surroundings of the discriminable forms be changed, since the form, seen with its surroundings, must be considered as part of a pattern. Even if no other objects are in the visual field the stimulus "is seen surrounded by the more or less irregular outline of the field of vision, and so is again part of a pattern."

To demonstrate experimentally whether the animal is reacting to forms or patterns, Hunter proposes that the electric chambers of the experiment box be fitted, after a perfect habit has been established, with hollow cylinders or hollow triangular prisms through which the stimuli may be seen by the reacting subject. He presents diagrams which, he declares, represent the discrimination situation in my experiment and in Lashley's study (20) of form perception in the rat.

Both series of experiments are concerned with *patterns* not forms. . . . In problem boxes such as those described by Lashley and Bingham . . . the animal tested is confronted *not* by two "*forms*" corresponding to the configurations of the opal glass, but by such designs as are suggested in figure 1. The squares drawn in the figure represent the rectangular tunnels down which the animal goes in making his responses. What the animal sees is a triangle or a circle each in more or less of a square setting.

Designs 4 and 5 represent Laskley's "forms."

Johnson (14) points out that Hunter's proposed method of control would introduce new olfactory stimuli and probably new tactile stimuli. Is there any means of deciding, he asks, whether failure to discriminate, after making such a change, resulted from the change of pattern or from the simultaneous introduction of other novelties? Furthermore, Johnson believes the change of a form stimulus from the right to the left compartment of the experiment box actually changes the background and foreground. This would therefore make the pattern a variable and the form a constant.

In addition to Johnson's reply to Hunter's contention, I have pointed out (3) the impossibility of pattern, in Hunter's sense,

serving as the discriminable factor. The conditions of control leave the rectangular tunnel constant but wholly change, if not destroy, the perceptibility of the environment.

That the animals could not see the environment is attested by the fact that they were frequently observed to walk blindly into the confining walls. Not all of the time was the environment "darkened," but the control tests were always made to determine whether, among other factors, setting was a factor in discrimination.

Figure 1, as presented by Hunter, does not accurately illustrate the condition of the stimulus areas. With the introduction of a screen as a means of control between the general illumination and the electric boxes and with the reduction of the intensity of the source lights, a similar condition to that illustrated in figure 2 appears. In the compartment where the triangle appears, the source light fails to illuminate the corners

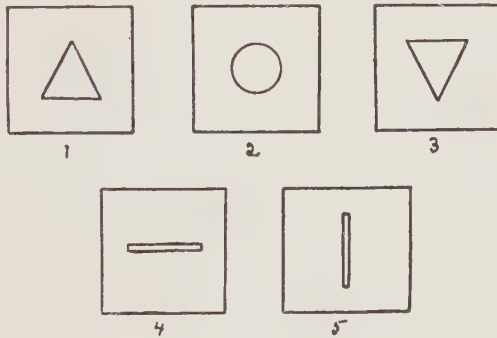


FIG. 1.

Reprinted from *Jour. Animal Behavior*, vol. 3, no. 5, p. 331.

of the tunnel, and so the perceptible portion of the setting changes to a sort of circular form as in diagram 1. About the circular stimulus, the visible setting is more nearly a perfect circle as is shown in diagram 2. Even if my apparatus offered a possibility of pattern discrimination, my plan of control (2: p. 98) would have made so variable the patterns confronting the animal that they never could have served as a basis of discrimination.

Hunter has apparently overlooked one of the essential features of the apparatus used in my study. The dark-room apparatus allows the experimenter to control the visibility of surroundings by means of artificial illumination. His criticism

would be valid for similar experiments conducted in natural and uncontrolled light. With the discrimination of stimuli continued under a varied visibility of surroundings the perception could not have been of patterns.

In a brief review, Washburn (32) dissents from my interpretation of form perception, declaring that she would conclude that the chick is not possessed of an abstract idea of triangularity. She says:

A triangle with apex up is a different form from a triangle with apex down: the two have in common only the abstract quality of three-sidedness. The perception of form, as distinct from an abstract idea of form, is based precisely on the unequal stimulation of different parts of the retina.

A portion of my later paper involves this lack of agreement in defining form (3). In that paper it is maintained that my

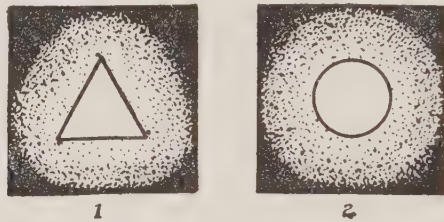


FIG. 2

Reprinted from *Journal Animal Behavior*, vol. 4, p. 137.

conception of form is in keeping with the ordinary usage of the term, and that we should not depart from the usual meaning in an effort to have it included in an animal's stock of perceptual experiences. If we find that our animals have a power of discrimination which approaches form perception, but which is not form perception in the strict sense of the term, we should adopt a terminology to fit the special case; we should not attempt to enlarge the scope of the old term to cover the special case.

Perhaps a more or less crude pattern vision is the nearest approach to form perception that animals possess. At any rate, Hunter has done well in calling attention to the distinction between patterns and forms. But our definition should not stop here. Two forms may be identical, but even in the ab-

sence of an orienting background or environment (pattern), as in the dark room studies, there may yet be a fundamental difference. This difference has been arbitrarily called "shape." An illustration of form similarities having shape differences is furnished in the experimental setting of Lashley's study. He used two identical forms in that both were rectangles 2 mm. by 60 mm. In his use, however, they differ in this respect: one is extended laterally thirty times as far as its vertical extension; the other is extended vertically thirty times longer than laterally. This has been defined as a difference in shape of two identical forms.

It is not to be denied that a triangle with vertex up differs from a triangle with vertex down, but one can scarcely say that they are different forms. They are both triangles, and more; they are equilateral triangles. Obviously it is desirable to adhere as far as possible to an explanation of the difference between these patternless stimuli in perceptual terms instead of resorting to ideational content. It seems useful to employ a term like "shape," therefore, which may differ in forms that are otherwise identical. When the extended base of the triangle is so placed as to stimulate the region of the retina which was formerly stimulated by the vertex of the triangle, a condition occurs similar to that pointed out regarding Lashley's forms: the forms remain identical, but the lines of maximum and minimum extension become interchanged. This fact led me to conclude in my paper (2: p. 110) that the apparent reactions to form are the result of keen perception of size differences. It seems probable that they are due to the perception of these so-called shape differences. The inversion of the triangle causes certain particular size changes—vertex or point interchanged with base or line—which introduces a change in shape, but no general change of size since the area remains constant. Similarly, the factor of triangularity remains constant and the form is unchanged. Not "the perception of form," therefore, but the perception of shape "is based precisely on the unequal stimulation of different parts of the retina."

Our definition, then, as separate from the distinction between forms and patterns, should distinguish between forms and shapes. Referring to the retinal area stimulated, there is form which is general, for example a triangle. But there is a partic-

ular feature about this general distribution of light—it is equilateral, or isosceles, or right angled—which is called shape. Forms are identical when their areas are equal and their general retinal distribution is similar. Shapes of forms are identical when all extension of the identical forms are equal and in corresponding directions. Thus, the area remaining constant, either or both form and shape may change. The form remaining constant, the shape may change. Change in form must always be accompanied by change in shape.

Unquestionably the test of form perception by inversion of the triangle is a severe one. But if this test of inversion is found to interrupt the discrimination, form perception in the strict sense of the term can scarcely be said to prevail. Moreover, there is evidence that form perception regarded not as an abstract idea but as perceptual phenomena does not exist.

More in line with Washburn's inclination to regard my interpretation of form as "an abstract idea of triangularity" (32) is my incidental observation (2) of reactions to relative stimulus difference. Because a few chicks showed ability to carry the correct large-small reactions from a 6-4 training to a 4-3 or 9-6 test situation, it would seem that the chick has some sort of ideational content. Watson, having been informed by Johnson that the latter failed to secure positive evidence in this relative stimulus problem with a single adult game bantam, hastily remarks (33): "From experiments now in progress at Nela Physical Laboratory (Johnson) it would seem that this observation cannot be confirmed." Johnson, however, is more conservative and disclaims Watson's unguarded remark by suggesting that the variation is due to individual differences particularly because it was found that not all of my subjects reacted positively to this problem. Moreover, I found only one chick that reacted positively and perfectly to *both* of the unfamiliar combinations. Doubtless, the amount of training has much to do with the nature of the reaction.

One of the best controlled studies employing the dark room-discrimination method is reported by Johnson (15-16). His report, appearing as two papers, is on the detail vision of the dog, the monkey, and the chick. The first paper deals with standardization of method in which he presents certain improvements upon the Yerkes-Watson apparatus. He commendably

points out that my discussion of controls (2) is ambiguous through my synonymous use of the words "intensity" and "brightness." The luminous intensity of a source, he declares, involves the total number of candles presented, but the brightness is the luminous intensity divided by the area of the source. The brightness, then, is measured in terms of candles per unit of area. In the light of this definition, Breed's use of the term "brightness" (5) is also open to criticism.

Regarding Johnson's assertion (15) that I reported "no control tests to show that discrimination was on the basis of size, rather than of luminous intensity of the stimuli," it is sufficient to note that variation of source distances would vary both brightness and luminosity. Independent variation of these two factors would be unnecessary so long as neither was allowed to remain constant. This control is adequately described in my report (2) on page 98.

Johnson's method consists in presenting striate fields for discrimination, adopting the visual angle subtended by one of the striae as a convenient measure of the animal's visual acuity. In terms of the visual angle subtended by individual striae, the stimulus threshold for the chick was found to be slightly above 4'. The standard individual striae were about 0.11 mm. in width, the assumption being that, at the given distance of 60 cm., "they were too small to be resolved by the eye." The minimum size of the variable individual striae discriminated from the standard striae was accepted for chick 1 as 0.710 mm. and for chick 2 as 0.743 mm. (16).

The refined dark room-color apparatus is used by Lashley (21) in studying the spectrum of the chick. Preliminary to his study of wave length and without using punishment as a motive, he finds that the brightness threshold is approximately three to one. In contrast with earlier work, this difference limen is unusually large. Aside from certain trivial errors in computations, Lashley's work seems to have been carefully done. He thinks that field experimenters may feel confident that differential reactions of birds to colored objects are made on the basis of wave length if the objects do not differ enormously in brightness for the experimenter. He concludes that "the chick can distinguish between monochromatic lights of any intensity between threshold and the Pfund standard, irrespective of the brightness or saturation. The effective stimulus is the wave length."

Finally, the latest paper dealing with chick reactions is by Fletcher, Cowan, and Arlitt (8a).⁴ They have made comparative observations of chicks hatched from normal eggs, from alcoholized eggs, from eggs with distilled water inserted, and from eggs merely pierced and sealed. Inherited and acquired reactions of these four groups were observed after the manner of Breed (4-5). They have contributed nothing to the topic of visual acuity.

In addition to this chick literature, studies in bird vision have been made by Porter (24a-24b) on the sparrow, cowbird, and pigeon; by Tugman (31) on the sparrow; and by Coburn (6) on the crow. In technique, the work of Porter is similar to that of Katz and Révész (17-18) but it reflects less ingenuity than the German papers. However, Porter's work was done a little earlier than that of Katz and Révész and he seems to have been better acquainted with the historical setting of his task. Coburn's and Tugman's studies have made use of recent available developments in the field of infra-human vision. These papers will receive further consideration in subsequent chapters where the results will be compared with my own results from the chick.

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PART II. EXPERIMENTAL

CHAPTER III

APPARATUS

The work on visual acuity, as reviewed in the preceding chapter, has been criticised primarily on the basis of method. One general fact stands out when these experiments on visual perception in the chick are viewed in their historical setting: the methodological aspect has rapidly come to be the central feature of the work. Beginning with loose observations in which accurate description of method was either impossible or ignored, the method has developed into a thoroughgoing scientific procedure. The early naturalistic observers raised questions for the later scientific school to solve. The naturalists have contributed a general orientation; the experimentalists are solving, one by one, the specific tasks involved. The apparatus used in the present experimental study represents an important stage in the development of technique for studying detail vision. Controllability was the primary aim in its construction. It represents a definite standardization which has been previously described in detail, hence my description will be a rapid summary. Supplementary to apparatus, but no less important, is experimental method and technique to which a special chapter will be devoted.

The dark room-discrimination apparatus has been carefully described in the report by Yerkes and Watson. In Chapter II, the origin and development of the method has been set forth. In figure 3 is presented an isometric view of the apparatus showing the skeleton of the various parts when assembled for work. That part of the mechanism labelled I is the *experiment box*. The opposite end, III, is the light or *source box*. Between the experiment box and the source box is the *stimulus shifter*, II.

1. *Experiment box*

An illustration of the experiment box appears as figure 4. This section of the apparatus is made of one-half inch lumber,

except where stated otherwise, and is painted within and without a dead black. It consists of four main parts: (1) *A* is an entrance chamber,¹ 20 by 15½ by 22. The floor of *A* is provided with a metal tray containing a layer of wet felt. The entrance

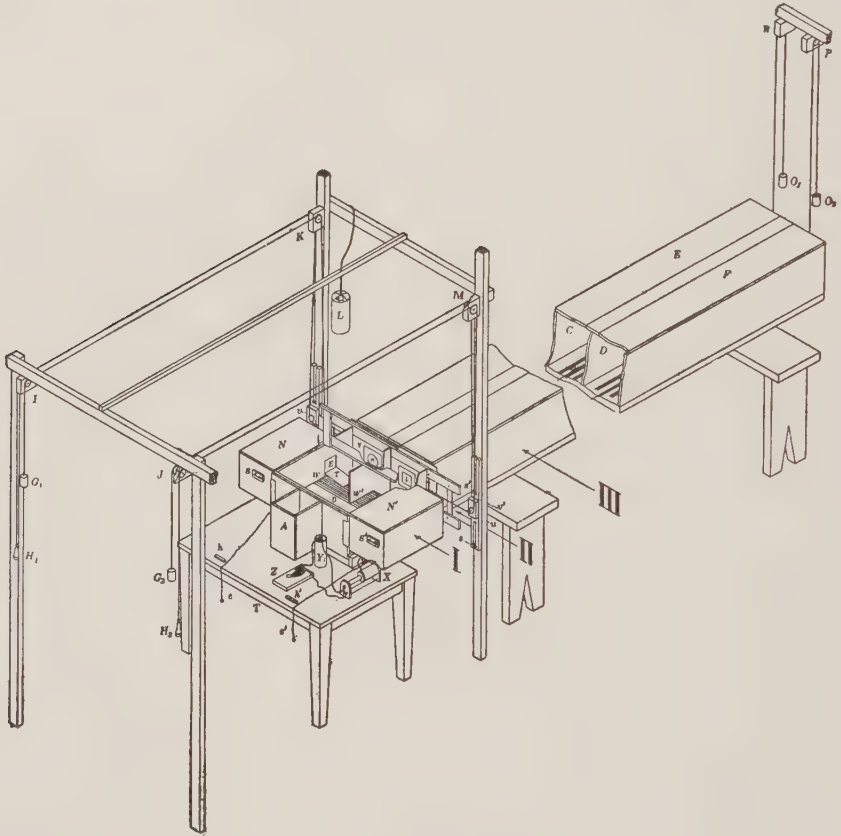


FIG. 3

Isometric view of *light* vision apparatus. Reprinted from *Journal Animal Behavior*, vol. 3, p. 67.

box may be removed by raising out of the iron straps, *C* and *C'*, the board to which it is attached. (2) *B* is a discrimination

¹ Unless otherwise stated, dimensions are given in centimeters and the order of presentation is length, width, and depth—inside measurements.

chamber, 26 by 51 by 22. Leading from *A* to *B* is an entrance, *I*, 8 by 10. The floor of *B*, like that of *A*, is carpeted with wet felt. The tray of either compartment can be easily removed and cleaned. (3) *W* and *W'* are electric boxes separated from each other by the partition *D*. On the floors of *W* and *W'* is a slab of slate carrying electric wires for punishment. By means of the interposed sides, *O O O*, the electric compartments are

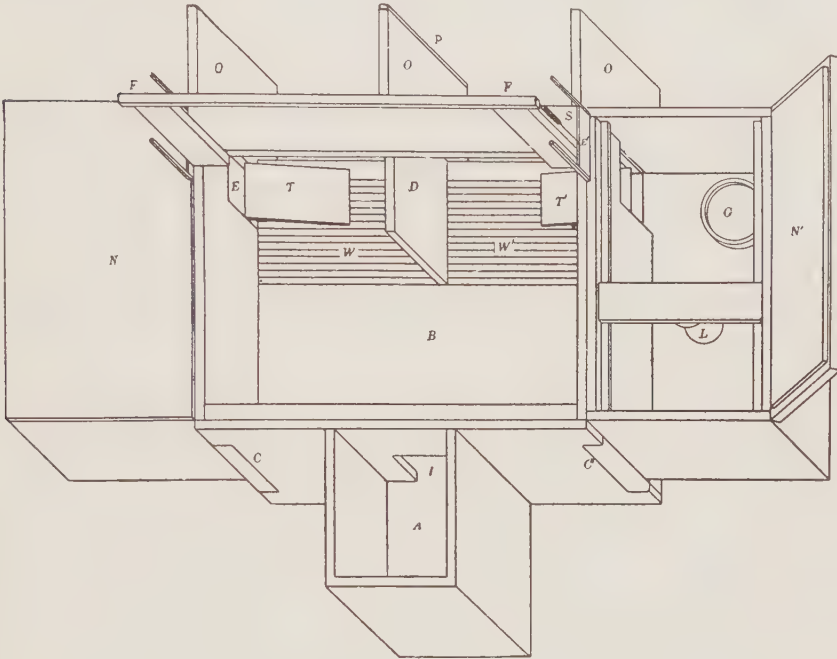


FIG. 4

Experiment box as seen from above. Reprinted from *Journal Animal Behavior*, vol. 3, p. 69.

set back 14 cm. from the stimulus shifter. The floor of this extended portion drops down about 10 cm. below that of *W-W'*. The middle *O* presses closely against the shifter so that the exposed stimuli are sharply separated from each other. On the end of *D-O* is glued a piece of piano felt, *P*, which rubs snugly against the shifter. (4) *N* and *N'* are nest boxes, $40\frac{1}{2}$ by 22 by 22. Each nest box is covered by a tightly fitting lid, which is

hinged at the outside, and is equipped with a 2 c.p. frosted electric lamp, a watch glass for water, and sand or litter in which food may be scattered. It is also provided on the outer side with hidden holes for ventilation.

Between *W* and *N* is a vertically sliding door, *E* closed and *E'* open, 3 mm. thick which fills an opening 8 by 10. Suspended from an upright frame, *F*, is a coiled spring, *S*, which passes through the walls of the experiment box to the top of *E*. When *E* is closed, *S* is extended and in a state of torsion, hence when *E* is released *S* tends to return to a state of rest and the doorway is opened.

The method of closing the exits is best illustrated in figure 3. A silk line, *e*, passing up through a wire loop directly under *E*, is attached to the lower part of the door. By pulling on *e*, the experimenter can close *E* which automatically locks when it is closed. By stepping on or striking *T*, the chick can release the lock. The experimenter, however, by catching *e* on the hook, *h*, can prevent the exit from opening when the lock has been released. This automatic release was devised by Professor F. S. Breed.

The construction of this mechanical device for locking and opening *E* appears in figure 5 where *T* is the trip that was seen in the other figures and *t* is a short piece of No. 30 black thread attached to *T* at *a*. Passing down through the floor, *F*, of the electric box, *t* runs over a pulley, *P*, and is fastened to the spring lock, *L*, at *b*. *B* is a block through which *L* passes and against which one end of the spring, *C*, presses. *D* is a stop attached to *L* supporting the opposite end of *C*. This spring tends to force *L* in the direction of *X* and to keep *T* in the position as illustrated. But when sufficient pressure is applied to *T* at any point above *R*, *L* is forced back in spite of the pressure of *C*, *E* is released at *X*, and the recoil of *S* raises *E*. When *E* is drawn down, *L*, by reason of the slanting end surface at *X*, is forced toward *P* until the notch of *E* has passed below the lower side of *L* when the constant pressure of *C* toward *X* forces *L* into the notch of *E* and the door is again locked.

In several respects, figure 5 is a poor representation of this tripping device. *L* is shown as constructed solidly in *B*, when, in reality, it slides freely through *B*. Moreover, *L* is shown in the figure as wide as the floor of the experiment box, but it is

really a delicate latch narrower than the width of *T* or *E* and is released by a slight touch upon *T*.

2. Source box

To provide illumination for the two stimuli simultaneously presented to the chick, the source box represented in figure 6,

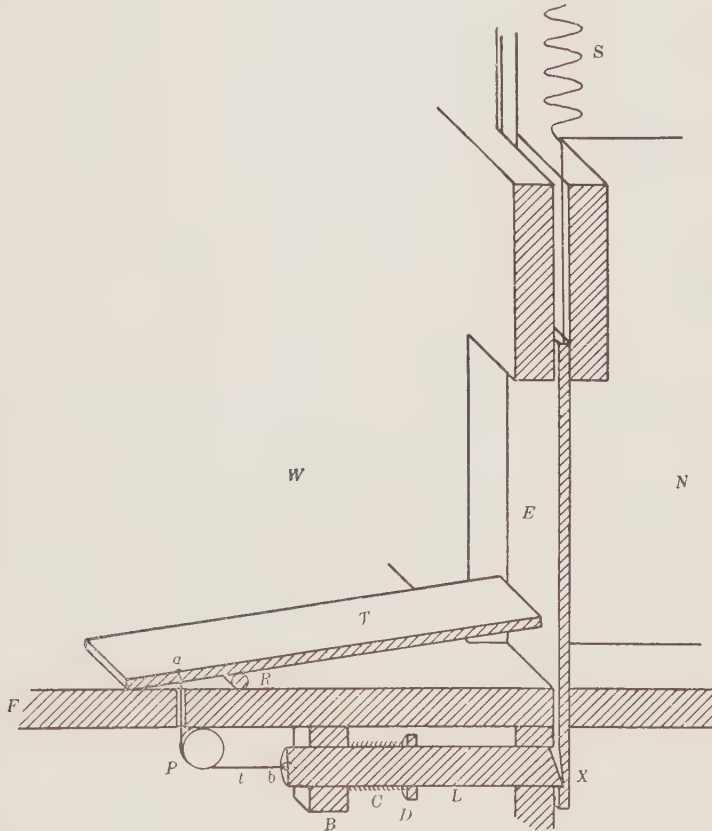


FIG. 5

Automatic tripping device of the experiment box. Reprinted from *Journal Animal Behavior*, vol. 3, p. 70.

—III of figure 3,—was used. A complete description of this part of the mechanism appears in *Behavior Monographs* from which figure 6 is reprinted.

3. *Stimulus shifter*

Figure 6 also presents a general view of the stimulus shifter, the primary function of which is control of the various visual details. The stimulus shifter or adapter is also described in *Behavior Monographs* along with the description of the source box.

A considerable number of stimulus plates, used for varying the size and form of the stimuli, is required for determining the chick's threshold for these spatial details. The majority of the plates used in this study is included in table 1. Owing to variations in sensitiveness among different subjects, a set which meets the requirements for one animal does not suffice for another, hence, in those cases where the size difference among the plates varies by one millimeter, a safe margin has been allowed by enumerating a few more plates than would ordinarily be required.

4. *Accessories*

In my report from which figures 3-5 are reprinted, there appears, on page 73 and following, a description of the details designed to aid in the control and manipulation of the mechanism just described. The punishing device and the upper illumination are also described. It is there shown how the experimenter from his position for observation, can control by means of ropes, pulleys, and weights the entire apparatus.

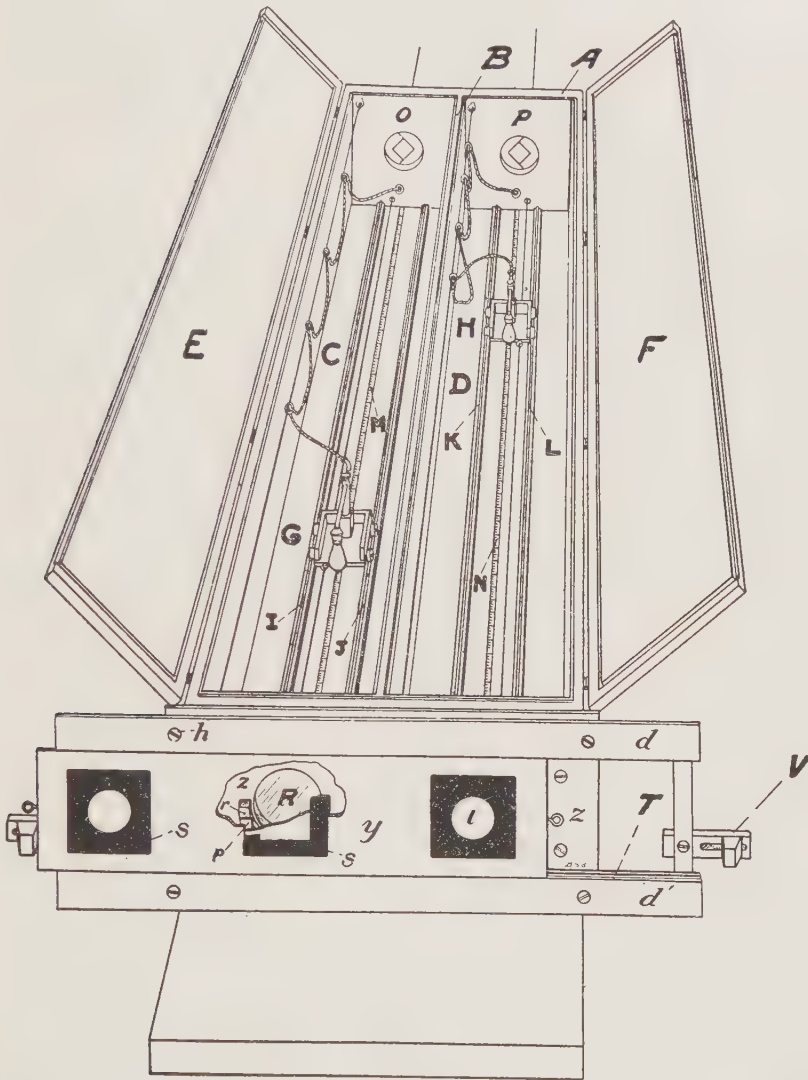


FIG. 6

Reprinted from *Behavior Monographs*, 1911, vol. 1, no. 2, p. 18. "Perspective of light or 'brightness' apparatus. A, light box; C, D, compartments of A; B, partition between C and D; E, F, lids of A; G, H, metal carriages carrying tungsten lamps; IJ and KL, tracks for G and H; M, N, Starrett steel millimeter tapes; O, P, apertures covered by Aubert diaphragms; R, Bausch and Lomb cooling cell in light box; d, d', metal straps; y, aluminum plate sliding between d and d'; T, tracks for y; V, stop for y; z, steel plate bolted to wooden end of light box; h, screws attaching d to z; s, s, standard brass stimulus plates; p, brass frame about aperture in y; r, hard rubber ring screwed to p."

TABLE 1
Stimulus Plates

USE	FORM	DIAMETER OR SIDE	AREA	NUMBER PLATES NEEDED
To test Size Perception	Circle	<i>cm.</i>	<i>sq. cm.</i>	
"	"	1.8	2.5447	1
"	"	1.9	2.8353	1
"	"	2.0	3.1416	1
"	"	2.1	3.4636	1
"	"	2.2	3.8013	1
"	"	2.3	4.1548	1
"	"	2.4	4.5239	1
"	"	2.5	4.9088	1
"	"	3.0 (standard)	7.0686	2
"	"	3.5	9.6211	1
"	"	4.0	12.5664	1
"	"	4.1	13.2026	1
"	"	4.2	13.8545	1
"	"	4.3	14.5220	1
"	"	4.4	15.2053	1
"	"	4.5	15.9043	1
"	"	4.6	16.6191	1
"	"	4.7	17.3495	1
"	"	4.8	18.0956	1
"	"	4.9	18.8575	1
"	"	5.0	19.6350	1
"	"	5.5	23.7583	1
"	"	6.0 (standard)	28.2744	2
"	"	6.1	29.2247	1
"	"	6.2	30.1908	1
"	"	6.3	31.1725	1
"	"	6.4	32.1700	1
"	"	6.5	33.1832	1
"	"	6.6	34.2120	1
"	"	6.7	35.2566	1
"	"	6.8	36.3169	1
"	"	6.9	37.3929	1
"	"	7.0	38.4846	1
"	"	7.1	39.5920	1
"	"	7.2	40.7151	1
"	"	7.3	41.8540	1
"	"	7.4	43.0085	1
"	"	7.5	44.1787	1
"	"	8.0	50.2656	1
"	"	8.5	56.7455	1
"	"	9.0 (standard)	63.6174	2
				44
To test Form Perception	Circle	<i>cm.</i>	<i>sq. cm.</i>	
"	"	6.0 (as above)	28.2744	—
"	"	5.9	27.3397	1
"	"	5.8	26.4208	1
"	"	5.7	25.5176	1
"	"	5.6 and smaller circles used in size perception	24.6301	1
"	Square	5.317 (side)	28.2743	2
"	Equilateral Δ	8.081 (side)	28.2743	2
<i>Openings inscribed in circle—28.2744</i>				
"	Square	4.243 (side)	18.003	2
"	Equilateral Δ	5.196 (side)	11.691	2
				12
Total.....				56

CHAPTER IV

PROBLEM, METHOD, AND TECHNIQUE

The experiments reported in the following pages were made with about thirty chicks belonging to four different groups. The first and fourth groups, each consisting of ten chicks, were secured from poultry breeders when the chicks were about two days old. The second and third groups were artificially incubated in the laboratory. The chicks used were Plymouth Rocks and all except two were of the Barred variety. The two exceptions were White Plymouth Rocks but neither contributes importantly to the final results. Properly caring for the chicks and keeping them healthy was one of the most serious difficulties which had to be overcome. On the whole, the laboratory hatched chicks proved more satisfactory.

The most common ills seemed to be due chiefly to improper feeding, irregular temperature, and inadequate ventilation. A few individuals of group 3 survived until the weather became warm enough for them to be out of doors during a few hours on favorable days. When this plan was first tried the birds were in poor condition. Two-thirds of the group had died. But as soon as the survivors were placed out of doors their physical condition began to improve, and it was possible to do nearly three times the amount of experimental work that could be formerly done. Evidently, the requirements for healthy laboratory chicks include an abundance of sunlight and fresh air with the necessity of working for a living.

The disease giving trouble with the first two groups was a type of "leg weakness," so called because the leg joints become enlarged, the toes curl out of shape, the chicks cannot stand, and they move about only with great difficulty. This trouble ultimately carried off nearly all of the birds which did not succumb to bowel disturbances. With one brood it was probably the result of excessive heat in the hover. In other cases it was probably due to overfeeding. More often, perhaps, it was due to a combination of both conditions. The birds which first

showed signs of this weakness were the largest and apparently the strongest of the flock. There was no evidence of it among the chicks of the third and fourth groups, which were fed sparingly and for which the temperature of the brooder was carefully regulated.

The matter of health among the chicks turned out to be a problem which had not been anticipated. However, it did not prevent work toward the solution of the primary problem. The task originally planned was a study of the chick's discriminative ability between sizes, forms, and brightnesses, but, owing chiefly to these unfavorable conditions, little consideration has been given to the third factor. Later tasks added to the original plan involve the perception of flicker and a study of the learning process and ideational content.

The aim has been to make the study intensive and quantitative. The question whether the chick can discriminate between stimuli differing with respect to a single visual detail is only a preliminary aspect of the problem. The primary task has been that of determining the least perceivable difference in detail vision. Breed's work indicates that chicks can discriminate on the bases of size and form. The work of Katz and Révész suggests the same possibility. My original plan, then, was to determine the threshold of difference for each of these factors.

With respect to size, my original plan was carried out with no essential changes, but with form, it was found necessary to abandon the original plan. In a short time it appeared that proper responses to stimuli differing only in form were not so readily acquired as reactions to size differences. After trying in vain for several weeks to train different subjects to discriminate between a circle and a triangle equal in area, the nature of the problem was considerably modified. It was clearly necessary to determine whether the chick, under the conditions of this experiment, could perceive form differences.

The task involving flicker perception, like that with forms, demanded first a preliminary answer. Other than the generally observed fact that birds are highly sensitive to moving stimuli, there were no experimental data at hand to indicate that a three or two to one flicker difference could be perceived. Beyond the study of a two to one discrimination, time and conditions have not permitted me to go.

The studies involving problem learning and ideation arose merely as incidents in connection with the more fundamental tasks. As the time of observing the chick's behavior in the various problems lengthened, there was a proportional increase of interest in the behavior itself. At last I gave in to a persistent desire to record quantitatively the chick's characteristic behavior in learning a particular task. From such an interest it is a natural step to questions pertaining to evidences of ideation in this learning. The problem of relative stimulus difference, incidentally discussed in Chapter IX, represents an initial approach to the study of the imaginal problem.

Finally, another aspect of the problem, also arising quite incidentally, was that of the relative value of the different visual details. My earlier results with forms, largely negative, emphasized the desirability of considering the factors in combination as well as in isolation. In its normal life the chick is not compelled to rely upon a single visual factor, but, on the contrary, it relies upon a natural combination of the visual details. It thus seemed desirable to start with complex stimuli and from this complex gradually to eliminate inequalities until a single visual factor remained. This method might furnish data on the relative value for the chick of the various visual factors.

The plan adopted for solving these various problems was the familiar Yerkes discrimination method. The description of the apparatus sets forth the general features of the method. Conditions both desirable and undesirable are presented to the chick. Either nest box contains those things which the chick wants. It provides food, light, warmth, and companionship. The experiment box is arranged to make the chick seek escape. In the entrance box the chick is closely confined; in both the entrance and discrimination chambers the floors are wet; the entire reaction box provides faint illumination, little warmth, no food, and no companionship. The chick's problem is to learn how to get from the undesirable to the desirable part of the apparatus. The two different stimuli are the signs by means of which the chick may learn which way to escape.

Each chick was taught the way of escape to the nest box by means of 20 preliminary trials. The entrance to the nest box at the side where the *right* stimulus appeared was open; the sliding door closed the entrance from the electric box where the

wrong stimulus was presented. The chick was allowed to go alternately to each nest box 10 times. It was thus made familiar with the nest boxes and the reaction box.

By displaying, always on the side of escape, the stimulus which the chick was later to be trained to choose, the subject was occasionally aided, prior to training, in acquiring a perfect habit.¹ This fact was especially noticeable in the experiments on size discrimination in which a circle 6 cm. in diameter always appeared in that electric compartment by way of which the subject escaped. At the end of the preliminary series a few chicks were responding perfectly to this condition of $\odot 28 + - \odot 7 +$ discrimination.² This perfect $\odot 28 + - \odot 7 +$ habit, however, may not mean that size was the basis of choice. It is quite probable that the chicks chose the lighter compartment. Precaution was taken to eliminate this possibility before size tests were completed, and control tests were introduced to make certain that it had been eliminated.

This preliminary work was followed by the training series. Both entrances to the nest boxes were now closed, and the only cues that remained to aid the chick in reaching the nest box were the two visual stimuli. Continuing with the example of size discrimination, $\odot 28 +$ was the positive sign, $\odot 7 +$ was the negative sign of escape from the experiment box. If a chick chose $\odot 7 +$ by stepping into that compartment, it was shocked by momentarily closing the key, *Z* of figure 3. A single shock was usually administered but if it were not effective it was repeated. The wet floors of A and B regulated the intensity of the shock. Care in the manipulation of the shock was important for it was essential that it be an effective punishment yet mild enough to avoid frightening the animal. The results of weeks of work could be destroyed in a moment through a blunder in the method of punishment.

In the early stages of training the chicks often went beyond the exit towards the stimulus at the end of the compartment. If the animal were allowed to do this it spent considerable time and energy around this illuminated stimulus. By placing a

¹ A habit is termed perfect when a chick successively makes 20 correct choices.

² The stimulus demanding a positive response is named first followed by the stimulus demanding a negative reaction. The dimensions represent the number of square centimeters in the area.

VISUAL PERCEPTION OF THE CHICK

35

RECORD SHEET

Subject

9

Date 12/7/11-1/2/12 Experiment Form Perception

Tests → Series ↓	1	2	3	4	5	6	7	8	9	10	R	W	REMARKS Average Time
A	l	r	l	r	l	r	l	r	l	r			
B	r	l	r	l	r	l	r	l	r	l			
1	r E-29	l 0-6	r E-59	l 0-19	r E-125	l 0-120	r E-56	l E-95	r E-65	l 0-44	4	6	61.8
2	l 0-4	l 0-24	r 0-36	r 0-30	l E-1-62	r 0-39	l 0-19	r E-2-180	l 0-15	r 0-33	8	2	44.2
3	r 0-67	l 0-8	r E-1-85	l 0-39	r 0-35	l E-2-141	r E-1-180	l E-1-24	r 0-5	l E-1-61	5	5	67.1
4	l 0-29	l E-1-42	r E-1-35	l 0-55	r 0-40	l 0-64	r E-2-100	l 0-30	r 0-32	l E-1-65	6	4	49.2
5	r E-2-84	l 0-8	r 0-9	l 0-12	r 0-10	l 0-6	r 0-18	l 0-26	r E-1-43	l E-2-38	7	3	25.4
6	l 0-11	l 0-14	r E-2-71	l 0-21	r 0-83	l E-2-41	r 0-28	l E-2-110	r 0-42	l E-2-18	6	4	54.6
7	r 0-44	l 0-31	r E-2-70	l 0-7	r E-1-8	l E-1-23	r 0-25	l 0-6	r 0-9	l E-1-56	6	4	28.3
8	r E-2-44	l 0-62	r 0-89	l 0-67	r E-2-71	l 0-58	r E-1-65	l E-1-56	r 0-24	l E-1-29	4	6	56.0
9	r 0-4	l 0-5	r 0-6	l E-1-20	r E-1-7	l 0-21	r E-2-42	l E-1-23	r 0-15	l E-1-16	5	5	15.9
10	l 0-4	l 0-4	r 0-5	l 0-31	r 0-106	l 0-19	r 0-61	l 0-5	r 0-10	l 0-45	10	0	39.5
11	r 0-10	l E-2-24	r E-2-138	l 0-35	r E-2-75	l 0-67	r 0-34	l 0-26	r 0-38	l E-1-81	6	4	60.2
12	r 0-6	l 0-37	r 0-22	l 0-10	r 0-14	l 0-12	r 0-8	l 0-8	r E-1-36	l E-1-14	8	2	16.7
13	r 0-8	l 0-7	r 0-40	l 0-45	r E-1-110	l 0-3	r 0-1-29	l E-1-20	r 0-21	l E-2-44	7	3	32.7
14	l 0-12	l E-1-120	r E-1-31	l 0-10	r E-1-10	l 0-74	r 0-12	l E-1-27	r 0-8	l E-1-31	5	5	33.8
15	r 0-38	l 0-11	r 0-22	l 0-8	r E-1-38	l E-2-54	r E-2-64	l 0-16	r E-1-39	l 0-5	6	4	29.5
16	l 0-18	r 0-8	l 0-21	l 0-30	r 0-5	l E-1-44	r E-1-42	l 0-33	r 0-11	l 0-28	8	2	24.2
17	r 0-42	l 0-37	r 0-40	l 0-11	r E-1-10	l E-1-58	r 0-62	l 0-30	r 0-28	l E-1-19	7	3	42.8
18	l E-1-60	r E-1-24	l 0-25	r E-1-35	l 0-20	r E-1-24	l E-1-25	r 0-15	l E-1-18	l 0-12	4	6	32.8
19	r 0-92	l 0-40	r E-1-44	l E-1-76	r 0-26	l E-1-58	r E-2-45	l 0-10	r E-2-27	l E-1-33	4	6	44.7
20	l E-1-12	l 0-34	r 0-8	l E-2-17	r 0-18	l 0-25	r 0-9	l E-1-60	r 0-42	l E-1-103	6	4	33.3
21	r E-1-22	l 0-12	r 0-13	l E-1-15	r 0-17	l E-1-26	l 0-11	r E-2-10	l 0-19	l E-1-40	5	5	18.5
22	l E-1-63	l 0-19	r E-1-40	l E-1-30	r 0-7	l 0-21	r E-1-23	l E-2-30	r E-1-46	l E-1-25	3	7	29.9
23	r 0-12	l 0-25	r 0-10	l 0-8	r 0-4	l E-2-41	r E-1-9	l 0-2	r E-1-10	l E-1-12	6	4	13.3
24	l 0-5	r E-1-44	l E-1-6	l 0-3	r 0-5	l 0-4	r 0-4	l 0-4	r 0-2	l E-1-45	7	3	12.7
25	r 0-14	l 0-12	r E-1-6	l 0-26	r 0-25	l 0-23	r 0-18	l 0-15	r 0-55	l 0-25	9	1	27.8

thin plate of glass across each compartment at a point just beyond the exit, the chicks were stopped near the exit and yet were not prevented from seeing the regular stimulus. As soon as they had learned the way of escape and had ceased trying to reach the stimulus, the glass plates were removed.

After a perfect habit had been acquired, the amount of difference between the two stimuli was decreased. When the $\odot 28 + - \odot 7 +$ discrimination became perfect, the situation was changed to $\odot 28 + - \odot 9 +$. The large circle was thus the standard which remained constant. The smaller circle was the variable which was successively increased in size until the animal could no longer choose correctly. This limit of correct choices was accepted as the chick's threshold of difference. The changes in diameter of the variable, it was found, could be

TEST SHEET

Title of investigation, Form: $\odot 28 + - \triangle 28 +$
 Experimented on, 9
 Harvard Psychological Laboratory, December 25, 1912
 Record Sheet, 1; Series, 15

TEST	BEHAVIOR	RECORD
1 r	$\overline{//} - /// + ///_a$	0-38
2 l	$/// + ///_a$	0-11
3 r	$\overline{//} + ///_a$	0-22
4 r	$// + // _a$	0-8
5 r	$/// - // \triangle^1 + ///_a$	E-1-38
6 l	$/// - /// \triangle^2 + // _a$	E-2-54
7 l	$// - /// \triangle^3 + ///_a$	E-2-64
8 l	$// + // _a$	0-16
9 r	$// + / \triangle^1 + // _a$	E-1-39
10 l	$/ + // _a$	0-5

6-4-29.5

REMARKS: Tendency to choose by position, *i.e.*, to go where it last escaped. Usually goes immediately to other compartment when it has been shocked for wrong choice.

as great as 5 mm. between $\odot 7 +$ and $\odot 12 +$ when presented with a standard $\odot 28 +$. Above $\odot 12 +$ the diameter of the variable was successively increased only by 1 mm.

For tabulating results, a *record sheet* which had formerly been used in the laboratory was well suited to my needs. It

provides for a concise summary of results. For the details of behavior, a *test sheet* was adopted. The 10 tests, horizontally arranged on the record page, appear vertically on the test page. After each one is a space for recording the details of the animal's behavior. At the right of the page is a narrow column for recording the results of the test—whether an error was made and the time for choosing. At the bottom is a space for further notes.

The manner of recording the details of the chick's behavior is illustrated in the accompanying *test sheet* which is a record of an actual series of tests. A set of symbols was used in order to follow fairly accurately the movements of an animal while in the discrimination chamber. Herewith is presented the key to the symbols used in these experiments:³

1. + = Approach to *right* compartment.
2. - = Approach to *wrong* compartment.
3. /, //, /// = Degree of attention based on behavior and time. A horizontal bar above any one of these symbols indicates unusually long time in this locality. For example,
 - a. $\begin{cases} + / & = \text{Brief consideration of } \textit{right} \text{ stimulus area.} \\ - / & = \text{Brief consideration of } \textit{wrong} \text{ stimulus area.} \end{cases}$
 - b. $\begin{cases} + // & = \text{Longer consideration of } \textit{right} \text{ stimulus area.} \\ - // & = \text{Longer consideration of } \textit{wrong} \text{ stimulus area.} \end{cases}$
 - c. $\begin{cases} + /// & = \text{Close consideration of } \textit{right} \text{ stimulus area.} \\ - /// & = \text{Close consideration of } \textit{wrong} \text{ stimulus area.} \end{cases}$
 - d. $\begin{cases} + \overline{///} & = \text{Long time before and close consideration of } \textit{right} \text{ stimulus area.} \\ - \overline{///} & = \text{Long time before and close consideration of } \textit{wrong} \text{ stimulus area.} \end{cases}$
 - e. $\begin{cases} + \overline{7} & = \text{Long time before but slight consideration of } \textit{right} \text{ stimulus area.} \\ - \overline{7} & = \text{Long time before but slight consideration of } \textit{wrong} \text{ stimulus area.} \end{cases}$
4. $\overline{\text{////////}}$ = Attention at entrance end; indifference to stimulus areas.
5. $\wedge$ = Approach on wires before *right* stimulus followed by retreat.

³ The symbols presented in print only approximate, as closely as is convenient, the written symbols actually employed during experimental observations. Printed substitutes, of course, are consistently presented throughout the text. The written symbols used for recording observations were selected as far as possible to represent concisely and accurately the behavior recorded.

6. $\vee$ = Approach on wires before *right* stimulus followed by wrong turn.
7. $\triangle$ = Approach on wires before *wrong* stimulus followed by retreat.
 - a. $\triangle^1$ = One shock
 - b. $\triangle^2$ = Multiple shock.
 - c. $\triangle^0$ = No shock.
8. $\odot$ = Turn around, clockwise; $\oslash$, counter-clockwise.
9. $\sim$ = Partial turn around, right to left; $\oslash$, left to right.
10. $\backslash$ = Position directly before division between each compartment; by turning head either stimulus area is visible.
11. $\prime\prime$ = Escape to nest box.
12. E = Error in choosing; this is followed by time in seconds.
13. 0 = Correct choice; this is followed by time in seconds.

For specific behavior in the electric compartments and remote corners of the experiment box, which it was desirable to record in gathering the data presented in Chapter VIII, the following additional symbols were used:

- $\sqcap, \sqcap, \sqcup$ = Right corner, left corner, or stimulus faced and apparently inspected.
- $\overline{\sqcap}, \overline{\sqcap}, \overline{\sqcup}$ = Right corner, left corner, or stimulus approached and inspected.
- $\sqcap, \overline{\sqcap}, \overline{\sqcup}$ = Right corner, left corner, or stimulus more closely approached and inspected.
- $\overline{\sqcap}, \overline{\sqcap}, \overline{\sqcup}$ = Right corner, left corner, or stimulus appropriately approached and inspected.

The preliminary series were begun during the second week, usually when the chicks were 10 days old. The experiments on space perception were conducted during the morning between the hours of eight and twelve. The experiment on flicker perception was conducted with less regularity during the morning and afternoon. On the whole, the early morning is the best time for experimental work with chicks. They are then most active for that is the time they naturally start out for food.

In the matter of rewarding with food, however, caution is necessary. A three-weeks-old chick will "fill up" in a short time if food is abundant. It then becomes sluggish. The plan was adopted of scattering only a few grains in the litter of the nest boxes so that the chick was kept active in working for its meal. This plan, when perfected, made it possible to increase the number of tests considerably above the maximum when the food was scattered less sparingly.

Up to this point considerable emphasis has been laid upon method and technique. Certainly an accurate solution of an

animal problem depends upon the adoption of a favorable method. The experimenter must use an apparatus by means of which he can accurately control the conditions of his study. He must also show alertness by controlling these conditions in such a way that his animals behave normally. Much animal stupidity, so-called, is really a reflection of human ignorance. The experimenter may lack animal intelligence by setting human problems for a lower animal to solve.

An animal frequently shows ingenuity in an unexpected direction, and if the experimenter be not alert he misses the most important part of the behavior. How many times this is the case, we cannot tell, for we only know of the cases where we did not miss the significant fact. A perfect method would make it impossible for the animal to pick up cues that were not intentionally offered by the experimenter. But it is through experience that we approach a perfect method, because there is always the possibility of improvement even in the best standardized methods.

The importance of method was impressed upon me through an incident in my experiments with the first group of chicks. I had inexcusably blundered by making the original conditions of discrimination too difficult for the chicks. They were being tested on $\odot 28 + \text{---} \odot 7 +$ discrimination. The subjects were allowed to go through the discrimination chamber and experiment box during the preliminary tests without regard to the position of the right or wrong stimulus; that is, both exits were open. When the training series were begun the brightnesses of the two stimuli were made markedly unequal and were irregularly varied from the first.

The experiment was begun with six subjects. As a partial result of my initial bungling, I had at the end of a few days only subjects 2 and 3 in suitable condition for further work. At the end of two and one-half weeks No. 2 gave up, but No. 3 persisted. At the end of the 24th series it had successively made three perfect series (see table 2). At the end of four more series it had reacted perfectly to the $\odot 28 + \text{---} \odot 9 +$ discrimination. The diameter of the variable was successively increased by 5 mm. until the variable $\odot 19 +$ was reached after which the diameter of the variable was changed by increments of 1 mm. The perfect responses continued with very few exceptions.

TABLE 2

Subject: 3. Hatched: 10/3?/11. Sex: Undetermined

SERIES*	DATE	RIGHT	WRONG	TIME†
	○ 28+ — ○ 7+ <i>Discrimination</i>			
1-21 (1-21)	Oct. 12-27	10	0	55
22 (22)	" 28	10	0	41
23 (23)	" 30	10	0	29
24 (24)	" 30	10	0	
	○ 28+ — ○ 9+ <i>Discrimination</i>			
1 (1)	Oct. 30	10	0	62
2 (2)	" 31	9	1	79
3 (3)	" 31	10	0	103
4 (4)	Nov. 1	10	0	55
	○ 28+ — ○ 12+ <i>Discrimination</i>			
1 (6)	Nov. 2	7	3	71
2 (7)	" 3	9	1	93
3 (8)	" 3	10	0	50
4 (9)	" 4	10	0	52
	○ 28+ — ○ 15+ <i>Discrimination</i>			
1 (11)	Nov. 4	6	4	112
2 (12)	" 6	9	1	68
3 (13)	" 6	8	2	44
4 (14)	" 6	8	2	51
5 (15)	" 7	9	1	52
6 (16)	" 7	9	1	40
7 (17)	" 7	8	2	41
8 (18)	" 8	10	0	52
9 (19)	" 8	10	0	62
	○ 28+ — ○ 19+ <i>Discrimination</i>			
1 (21)	Nov. 8	8	2	49
2 (22)	" 9	8	2	49
3 (23)	" 9	8	2	90
4 (24)	" 9	10	0	50
5 (25)	" 10	8	2	78
6 (26)	" 10	10	0	53
7 (27)	" 11	10	0	47
	○ 28+ — ○ 23+ <i>Discrimination</i>			
1 (6)	Nov. 11	8	2	58
2 (7)	" 13	8	2	116
3 (8)	" 14	10	0	41
4 (9)	" 15	8	2	45
5 (10)	" 15	10	0	16
	○ 28+ — ○ 24+ <i>Discrimination</i>			
1 (21)	Nov. 17	10	0	22
2 (22)	" 17	9	1	30
3 (23)	" 18	10	0	16
4 (24)	" 18	10	0	11

* Numbers in parentheses refer to series on record sheet.

† Average time for series given in seconds.

TABLE 2—Continued

SERIES*		DATE	RIGHT	WRONG	TIME†
		○ 28+ —	○ 25+ <i>Discrimination</i>		
1	(11)	Nov. 21	9	1	22
2	(12)	" 21	10	0	16
3	(13)	" 21	9	1	17
		○ 28+ —	○ 26+ <i>Discrimination</i>		
1	(16)	Nov. 22	10	0	15
2	(17)	" 22	9	1	24
3	(18)	" 23	7	3	45
4	(19)	" 23	10	0	23
		○ 28+ —	○ 27+ <i>Discrimination</i>		
1	(21)	Nov. 23	8	2	20
2	(22)	" 23	8	2	25
3	(23)	" 24	6	4	33
4	(24)	" 24	10	0	11
5	(25)	" 24	9	1	30
		○ 28+ —	○ 28+ <i>Discrimination</i>		
1	(1)	Nov. 25	10	0	?
2	(2)	" 25	6 (crack closed)	4	?
3	(3)	" 25	0	5	?
		○ 28+ —	○ 23+ <i>Discrimination</i>		
1	(16)	Nov. 27	5	5	62
2	(17)	" 27	5	5	59
		○ 28+ —	○ 19+ <i>Discrimination</i>		
1	(18)	Nov. 28	3	7	71
		○ 28+ —	○ 15+ <i>Discrimination</i>		
1	(19)	Nov. 28	9	1	60
		○ 28+ —	○ 19+ <i>Discrimination</i>		
1	(20)	Nov. 29	6	4	73
2	(21)	" 29	5	5	83
3	(22)	" 30	7	3	31
4	(23)	" 30	7	3	22
5	(24)	" 30	5	5	23
6	(25)	Dec. 1	5	5	27

* Numbers in parentheses refer to series on record sheet.

† Average time for series given in seconds.

Finally the behavior of the chick indicated that it was discriminating between ○ 28+ and ○ 27+ (see record for November 23 and 24).

The discrimination of such a minute difference was incredible, for the human eye could scarcely detect a difference after the variable reached ○ 23+. The next step was to try the chick

when the variable was made equal to the standard. The result was a perfect series (see record 1 for November 25).

With positive evidence that the discrimination was not of size difference, an inventory of possibilities was taken. Among the features noted was a small crack where the outside extension of the electric source box jointed to the experiment box. But a similar crack appeared on both sides in corresponding positions, so it seemed that in this factor there could be no cue by which the chick had been guided in its choice of the proper compartment.

Closer inspection, however, proved that these two minute cracks lay at the bottom of the matter. Where the rabbeted edges of the shifter and tracks rubbed, there was a bright edge, and wherever the shifter rested the bright surface was covered. Thus when the shifter was at the left, the right end of the track was uncovered, and from this uncovered part were reflected some of the light rays from the upper illumination. A small portion of this reflected light could enter the crack on the uncovered side. Now, when the standard circle was presented at the left, the shifter was always moved to the right; when the standard stood at right, the shifter stood at the left. As a result, the crack that was illuminated was always the one where the standard circle was displayed; the other crack, being reached by no reflected light, was comparatively dark.

The effect of closing these small cracks through which the light was reflected is indicated in the records following the first on November 25. The perfect reactions abruptly cease; out of 15 tests there are only 6 correct responses. As the following portion of the table indicates, the experiment with the cracks closed was continued, but the variable had to be reduced to $\odot 15+$ before the correct reactions returned.

The chick, then, had detected a faint streak of light not more than 6 mm. long and less than 1 mm. wide or else the increase in general illumination which resulted. By considering the amount of light that came from the upper illumination, the poor reflecting surface of a steel strap worn only moderately bright, and the narrow surface from which the light was reflected, (not more than 1 cm. in width), the insignificance of this strip of light is emphasized. It was an example of the chick "outguessing" the experimenter.

CHAPTER V

SIZE PERCEPTION

The foregoing discussion of method suggests the difficulties that arise when one's experimental problem becomes limited to a single detail of vision. It emphasizes the uncertainty of earlier work where exacting controls were not employed. In the light of my experience, it seems to be a safe guess that prior studies, presumably of detail vision, were, in fact, studies of reactions to visual complexes the constituents of which were not known to the experimenters. The control, in my study, leading to the discovery of the disturbing crack proves that the results with chick 3, prior to the control, were untrustworthy. In other studies where the possibilities for similar disturbances have been many times greater, results should be accepted with considerable caution.

After the discovery of the light-admitting crack, my results become more reliable. Later experiments with chick 3 indicate that the early positive choices had been made on the basis of a discrimination of size difference, but as the variable became larger, and the discrimination proportionately harder, the chick resorted to a different criterion for choosing. In table 2 one finds evidence of the place where chick 3 ceased to discriminate between the two size stimuli. After the controls, the chick was first tested with a variable $\odot 23+$. The results are clearly negative since chance alone is sufficient to explain the number of correct responses. With the variable reduced to $\odot 19+$, there are only three correct choices in ten tests, but when the variable was changed to $\odot 15+$ the results are clearly positive. The standard was chosen nine times and the variable only once. While the average results of the tests with the $\odot 19+$ are slightly in favor of the larger stimulus, it seems that one should not emphasize the fact for the larger circle was chosen, in a total of 60 tests, only five more times than chance allows.

Table 3 summarizes the results of my study of the chick's perception of size stimuli. In contrast with earlier reports

TABLE 3
Discrimination Between Unequal Circles

SERIES	NO. 3 ¹						NO. 6 ²						NO. 7 ³						NO. 15 ⁴						NO. 16 ⁵					
	28+	7+	28+	12+	28+	15+	28+	7+	28+	12+	28+	15+	28+	7+	28+	12+	28+	15+	28+	7+	28+	12+	28+	15+	28+	7+	28+	12+	28+	15+
	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W
1.....			5	5	9	1			7	3	8	2	8	2	8	2	10	6	7	3	9	1	10	0	7	3	9	1	8	2
2.....			8	2		³			9	1	8	2	4		6	4	9	1	7	3					7	3				
3.....			6	4					9	1	8	2			7	3	7	3	4						8	2				
4.....			8	2					8	2	6	4			9	1	8	2												
5.....			9	1					10	0	8	2			9	1	9	1												
6.....			6	4					9	1	6	4			9	1	8	2												
7.....			10	0					8	2	8	2			10	0														
8.....									6	4					8	2														
9.....									9	1					10	0														
10.....									10	0					10	0														
11.....									8	2					10	0														
12.....									10	0					10	0														
13.....									10	0					10	0														

¹ Precord by tests which were ruled out on account of the crack of light.

² The record for $\odot 28+ - \odot 7+$ was preceded by 13 series in which the light factors were combined; the record given represents the first series after all factors except size were eliminated.

³ Followed by $\odot 28+ - \odot 19+$ in which No. 3 failed.

⁴ Tests were hurried on account of physical condition of subject.

TABLE 3—Continued
Discrimination Between Unequal Circles

SERIES	NO. 17 ♀ ²						NO. 18 ♂ ²						NO. 20 ♂(7) ³						NO. 21 ♀ ²					
	28+	7+	28+	12+	28+	15+	28+	7+	28+	12+	28+	15+	28+	7+	28+	12+	28+	15+	28+	7+	28+	12+	28+	15+
	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W	R	W
1.....	10	0	10	0	8	2	8	2	10	0	8	2	9	1	8	2	7	3	7	3	10	0	10	0
2.....					9	1					5	5					7	3					7	3
3.....											8	2					6						8	2
4.....											5												8	2
5.....																							6	4
6.....																							10	0
7.....																								
8.....																								
9.....																								
10.....																								
11.....																								
12.....																								
13.....																								

²The record for ♂ 28+—○ 7+ was preceded by 13 series in which the light factors were combined; the record given represents the first series after all factors except size were eliminated.

³Became discouraged.

⁴Tests ended on account of physical condition of subject.

which emphasize habit formation my results do not always appear clear cut and definite. Frequently the positive choices that have been allowed to pass as though satisfactory do not exceed 75 per cent of the total, whereas earlier work seems to have been more regularly favored with ultimate perfection. Does this not indicate that my results are untrustworthy?

In general, there are two answers to this possible criticism. I shall refer first to the least important, namely, that my task was not one in habit formation. Perfection of a habit was only incidental to the primary task of sensory acuity. Experience with the first group of chicks indicated that time was wasted by holding rigidly to the perfection requirement. The uncertainty of the chick's health, further, made it advisable to hasten towards the threshold of discrimination without waiting in all cases for perfect habits.

Chicks 6 and 7, representing the first group, were held to the preliminary training, $\odot 28 + - \odot 7 +$, until two successive perfect series were obtained. Then the variable was changed to $\odot 12 +$. From the first, there was evidence of discrimination of this new variable but only a single perfect series appeared. After six or seven series, there was no evidence of improvement over the beginning of the $\odot 12 +$ discriminations. This suggested that time could have been saved by increasing the variable as soon as there was satisfactory evidence of discrimination, even though positive reactions had not reached 100 per cent.

With the second group, including chicks 15-18, therefore, this suggestion was tried out. The series numbered 1 in table 3, which was the 14th for this group of chicks, represents the final series of the preliminary training. In that series chick 17 is the only one to react perfectly. But the reactions of 15, 16, and 18 were so closely approaching perfection that there was unmistakable evidence of discrimination. Moreover, it was more convenient to present to the other chicks the same stimuli which were presented to chick 17. Without further training, then, all chicks of the group were confronted with the new variable, $\odot 12 +$.

That such haste was justified is indicated in the single $\odot 28 + - \odot 12 +$ series for each individual of this second group. Chicks 15, 17, and 18 responded perfectly while the positive responses of No. 16 are 8 out of 10. Again, when the variable

was increased to $\odot 15+$, chick 16, the only individual of the group which had failed to make a perfect record in one of the two preceding tests, is the only one in this series to make a perfect record.

Comparing, now, these records of chicks 15-18 with the records of chicks 6 and 7 of the first group, the haste is further justified. Chicks 6 and 7, after continuing in the easy training until the reactions were well perfected, subsequently fail to show up superior to chicks 15-18. Furthermore, the records of chicks 20 and 21, belonging to group 3, are no less clear cut for the variables $\odot 12+$ and $\odot 15+$ than the records of chicks 6 and 7.

The second answer to this possible criticism is more theoretical than the first, but the two are closely allied. A review of the actual results indicates that it was not essential to insist upon 100 per cent correctness. In the second place, mine is a study of detail vision in the strict sense; earlier studies, though presuming to present data on visual details, have probably dealt with visual complexes. For this reason, my results cannot be justly estimated by means of the same criteria that have been adopted in connection with earlier work. In studies of detail vision, animals are compelled to react appropriately to a single visual factor. Now, when the remaining factors happen to be so grouped that the complex becomes especially attractive,—and well controlled tests will contain such combinations,—is it surprising that the attractive complex gains the attention of the animal for the time being and causes the animal to ignore the more insignificant single visual detail? In control tests, one is always demanding, in the face of other attractions, responses to this more or less insignificant factor. Due allowance should be made for momentary lapses of the attention of the animal.

Furthermore, as the threshold of the particular visual factor is approached, the single detail becomes less and less significant. It is reasonable to suspect, then, that even before the perceptibility of the discriminable detail wholly vanishes, the animal will be tempted to try out novel reactions. On the analogy of human behavior, it seems reasonable that the animal actually ignores at times the discrimination problem that has been set. This supposition is especially plausible when we consider that the vividness of punishment may decline as the discrimination habit approaches perfection. Making allowance, then, for

these interruptions, which are certainly not indicative of inability to perceive the visual detail in question, wholly perfect responses when the threshold is being approached cannot reasonably be expected.

By considering, in addition to the correct records, the peculiarities of behavior which cannot be presented in tabular form,¹ I am convinced that the largest variable which the chick can distinguish, under the conditions of this study, when presented with a standard $\odot 28+$, lies somewhat above $\odot 15+$. The quantitative measurements on the basis of correct choices supports this conclusion. Every subject, excepting 7 and 20, succeeded in making at least 80 per cent of the choices correct in a series when the $\odot 15+$ variable was used. Even in the re-

TABLE 4
Average time for choosing

SUBJECT	$\odot 28+ - \odot 7+$	$\odot 28+ - \odot 12+$	$\odot 28+ - \odot 15+$
6	15"	13"	7"
7	22	59	55
15	8	5	31
16	30	28	11
17	3	8	13
18	4	3	20
20	3	13	11
21	6	2	9
Average for all subjects.....	11"	16"	20"

sponses of 7 and 20, an efficiency of 70 per cent was indicated. But more convincing, perhaps, is the fact that two chicks, 3 and 17, reached 90 per cent and two, 16 and 21, made perfect series.

The time used by the chicks in choosing is a factor which might throw supplementary light on this threshold question. Having kept the time for every choice, and having casually observed changes in time for choosing in the beginning, intermediate, and final stages of discrimination, it is at least interesting to note whether the actual time records confirm this observation. In table 4 appears the average time in seconds consumed by each of eight subjects for choosing under the three different discrimination settings. An average of the

¹ See sample test sheet, page 36, for method of recording these peculiarities of behavior.

averages for the eight subjects gives respectively for these discrimination settings 11, 16, and 20 seconds. These averages indicate that the chicks in the early stage of learning were faster in choosing than in the intermediate stage. However, the reliability of these averages as an index of discriminability is open to question. The frequency of errors indicate that less discrimination underlies the early responses. While the chicks were less acquainted with the conditions of the experiment in the initial training, variable $\odot 7+$, they made many direct choices without showing evidence of comparison such as frequently occurred when the discrimination habit had become well established. Less time naturally was recorded for these direct choices, although errors were more frequent. Apparently the averages of No. 21 as recorded in table 4 are more reliable as an indication of the relative time required for each setting where discrimination underlies the choices. The time of this chick for each of the three variables is respectively 6, 2, and 9 seconds. If it were possible to obtain an average for the time of those responses only in which choice was based on discrimination, it is probable that we would find the time greater in the beginning and final stages than in the intermediate stage. During the intermediate stages the habit would be well established and the discrimination settings would not be extremely difficult.

It might be urged that this time average became relatively longer towards the close of the experiments on account of the physical condition of the chicks. The facts, however, seem to refute such a view. Referring again to the individual record of chick 21 in table 4, one finds evidence that the changes in time averages are not conditioned by the health of the chicks. During the course of these tests No. 21 was given open air range under which conditions it thrived and grew normally. This chick continued in good health even at the end of 1500 subsequent tests in form perception. The records of table 4 indicate that chick 21 was slower with the variable $\odot 7+$ when it was learning, the average time was *not* increased when the variable was changed to $\odot 12+$ because the discrimination remained easy, but the time *was* increased when the more difficult discrimination, variable $\odot 15+$, was required.

The records of chick 21 alone cannot be accepted as reliable on account of the limited number of tests, particularly in the

intermediate stage. On the other hand, one might assume with some justice that, in more than 2000 tests distributed among eight individuals, all irregular fluctuations would tend towards an equal distribution among the different size relations. In this event, the time records represented by the final averages of table 4 might be said to substantiate the preceding conclusion, based upon the number of correct choices, that the maximum which the chick can discriminate under the conditions of this experiment lies somewhat above ϕ 15+.

Statistically considered, however, the averages of this table have very little significance. The mean variation, for example, from the 11, 16, and 20 seconds averages are respectively 8, 13, and 12 seconds. These mean variations are nearly as great as the averages themselves, and they are, in every case, as great as or greater than the differences between any two of the averages.

These averages of table 4 are even more questionable when one considers the individual records on which the table is based. A notion of these individual records may be derived from Test Sheet 1 and Test Sheet 2 which are presented to illustrate how the behavior respectively differed under easy and difficult discrimination. Taking these two series as examples, we find that the mean variation represented by Test Sheet 1 is 1.88 seconds which is nearly 59 per cent of the average for the ten tests. In the records presented by Test Sheet 2, the mean variation is a little lower being slightly above 51 per cent. This wide variability suggests that the averages for the different individuals are themselves questionable. Combining with this the variability noted within the table itself, these averages appear as doubtful criteria.

A number of things might be mentioned in explanation of the variability between the tests of a single series. Wholly secondary influences, such as a severe shock, the slamming of a door, or a snow slide on the roof, are often responsible for a sudden fluctuation in the reaction time. A more natural difficulty with the chick which is responsible for even greater fluctuations in reaction time is a tendency to go to "roost" in the dark room. It can usually be aroused by blowing lightly against the feathers, but such behavior plays havoc with the reliability of the individual time records.

TEST SHEET 1

Title of investigation, Size: $\odot 28+$ — $\odot 7+$

Experimented on, 21

Harvard Psychological Laboratory, February 28, 1912

Record Sheet; 1; Series, 6

TEST	BEHAVIOR	RECORD
1 l	$// + ///_a$	0-4
2 l	$+ \overline{///}_a$	0-5
3 r	$+ \overline{///}_a$	0-2
4 l	$+ \overline{///}_a$	0-1
5 r	$+ \overline{///}_a$	0-2
6 r	$+ \overline{///}_a$	0-2
7 l	$+ \overline{///}_a$	0-2
8 r	$+ \overline{///}_a$	0-2
9 l	$+ \overline{///}_a$	0-2
10 r	$+ \overline{///} \overline{////}_a$	0-10

10-0-3.2

TEST SHEET 2

Title of investigation, Size: $\odot 28+$ — $\odot 7+$

Experimented on, 16

Harvard Psychological Laboratory, March 6, 1912

Record Sheet 1; Series 16

TEST	BEHAVIOR	RECORD
1 l	$\overline{///} - // + /// \vee - \overline{///} + ///_a$	0-47
2 r	$/// - // \bigcirc + ///_a$	0-38
3 l	$\overline{///} + - + // - \overline{\Delta^1} + - // \Delta^1 + //_a$	E-2-58
4 l	$// + \overline{///} \wedge \bigcirc - /// + ///_a$	0-35
5 l	$/// + ///_a$	0-11
6 r	$/// - \overline{///} // \Delta^1 + ///_a$	E-1-21
7 r	$// + /// - /// \bigcirc + ///_a$	0-22
8 r	$+ ///_a$	0-5
9 l	$+ /// \overline{\bigcirc} - /// \overline{\bigcirc} + ///_a$	0-35
10 r	$// + ///_a$	0-10

8-2-28.2

The characteristics of the chicks' behavior offer a less precise basis for determining the location of the threshold. This type of evidence, however, is practically limited to the observer. It can scarcely be conveyed to the reader. Yet, despite the limitations of such evidence, the fact remains that the observer has a qualitative criterion which he may employ in addition to his quantitative measurements. If both agree he naturally feels more certain of his conclusions.

The two test sheets presented illustrate two different types of behavior. Test Sheet 1 shows that chick 21 lost no time on entering the discrimination chamber, but went directly in every test to the correct compartment. Test Sheet 2 presents a different type of behavior, yet it indicates that chick 16 was discriminating between the two stimuli. In the first test the chick was quiet for some time after entering the discrimination box; then it went to the wrong side where it stopped momentarily. It then turned to the left, went close to the left electric compartment, hesitated, and entered but turned to the right and came out. Again it looked closely at the wrong (right side) stimulus, turned back to the correct stimulus (left), and escaped. The behavior was somewhat similar in the second test except that in turning away from the wrong stimulus, which was this time at the left, the chick turned its self completely around, counter clockwise, and came up before the correct stimulus. The third test shows that chick 16 made two errors for both of which it was punished. In test 9 the chick made two complete turns—one counter clockwise from the correct compartment (left side), and one clockwise turn from the other compartment.

These two test sheets have been selected with an idea of showing as marked contrast as possible in order to emphasize the importance of the chick's behavior during each test and series. The first shows that chick 21 had no difficulty in choosing the proper stimulus. The second indicates that chick 16 was comparing the stimuli and using considerable care in choosing, although it made two errors. The choices alone do not indicate as much advancement as the details of the behavior during the choices. These two series cannot be called typical yet they represent fairly well some of the essential principles of behavior in the discrimination problem.

On the basis of choices and behavior—it seems safest to exclude the time factor—it appears that the chick's limit in discrimination from a standard $\odot 28+$ lies somewhere between $\odot 15+$ and $\odot 19+$. To express the relation in terms of centimeters instead of square centimeters, the size in diameter of the variable is above 4.5 but below 5; that of the standard is 6. *The threshold of difference with a standard 6, therefore, is one-fourth to one-sixth.*

To be certain that the reactions of the chicks were not made on the basis of some detail or complex other than size difference, it was necessary to employ various controls. There appear, in the stimuli themselves, three factors other than size that might provide a basis for correct response: (1) luminous intensity of the respective stimuli; (2) brightness of the respective stimuli; and (3) illumination of the respective electric compartments. Without adequate controls, it would be impossible to say definitely whether size or these other characteristics were the bases of the responses which point to the above conclusion.

Supposing the two stimulus areas to be 6 cm. and 3 cm. in diameter, the display surfaces equal in brightness, and a complete image of the larger formed on the retina, it follows that the chick would be stimulated by four times as much light from the larger as from the smaller stimulus. It is conceivable that the chick, under these conditions, might respond on the basis of pain or its physiological concomitant, or even of pupillary reaction. In addition to this possibility, the general illumination of the electric compartment containing the larger stimulus would differ from that of the other compartment. The chick might choose the lighter or darker compartment. Both of these possibilities might occur independently of the matter of brightness.

As a portion of the controls used in this connection, an additional lamp was placed directly above the experiment box. This upper illumination (L of figure 3, p. 24), consisting of a 2 c.p. electric lamp enclosed in a vertically suspended cylinder of galvanized iron, was designed to hide the inequalities in the distribution of light in each compartment. It hangs about 120 cm. above the floor of the experiment box so that an equal amount of light is added to each compartment. The diameter of the cylindrical enclosure is 10 cm. and its length is 20 cm.

The upper end is tightly closed. The lower end is fitted with a removable cover in which is centered an Aubert diaphragm for regulating the amount of light falling upon the experiment box. To eliminate shadows in the experiment box and to increase the amount of upper illumination, the diaphragm cover was removed throughout the greater part of the experiment. With the lower end of the cylinder open, the amount of light added to the experiment box was that coming from a 2 c.p. lamp, passing through a circular opening 10 cm. in diameter, and falling a distance of 120 cm. Further variations in the upper illumination were made by substituting for the 2 c.p. lamp, after the chicks had acquired a positive reaction tendency, larger lamps with a maximum of 10 c.p.

The upper illumination thus serves as a control of the inequality of general illumination in the two electric compartments. It can be so arranged as to furnish enough illumination, equally divided between the two compartments, to reduce the proportional difference in illumination to a point below the chick's threshold. The amount of upper illumination should therefore depend upon the degree of difference between the sizes and brightnesses of the two stimulus areas. In a quantitative study, where the difference in size is being continually reduced, and where variations and reversals of brightness are essential features of the vital tests, the possibility of consistent reactions on the basis of difference in general illumination is removable by means of the upper illumination.

Variations and reversals of brightness, as essential parts of the system of control, are easily effected by changing the respective distances of the source lamps from the display surfaces. If the brightness of the respective stimuli be varied by reducing the illumination of the larger, increasing that of the smaller, or *vice versa*, the luminous intensity of the stimuli is at the same time varied. Thus, a proper combination of controls, including the upper illumination and relative changes in distance of the sources, provides a means of determining whether the basis of the chicks' choices lies in size difference or any of the three possibilities (1) luminous intensity, (2) brightness, and (3) general illumination.

The method of adapting these controls to my experiment is concisely stated in table 5. The location of the source lamps

was varied according to the plan of the second and third columns. The illumination of the electric compartments was controlled as indicated by the last two columns. In tests 1 and 2, the + or correct stimulus area was considerably brighter and the corresponding compartment lighter than the other. In

TABLE 5
Control series for $\odot 28+ - \odot 7+$ Discrimination
Nos. 15, 16, 17, 18, 20, and 21
March 4, 1912
Record Sheet 1. Series 14

TEST	SOURCE DISTANCE FROM		GENERAL ILLUMINATION OF	
	+ Stimulus	- Stimulus	+ Compartment	- Compartment
	cm.	cm.		
1 l	240	125	Uncontrolled except for upper illumination	
2 l	240	125	"	"
3 r	240	125	Much darker: Covered with 2 thicknesses of ground glass	Much lighter: Covered with thin sheet of plain glass
4 l	240	125	Darker: Covered with 1 thickness of ground glass	Lighter: Covered with 1 thickness of plain glass
6 r	240	240	"	"
7 l	180	180	"	"
8 r	180	180	"	"
9 l	180	180	"	"
10 r	180	180	"	"

tests 3 and 4 the general illumination was reversed without changing the brightness or luminous intensity of the stimulus areas. After test 5,² the source controls remain unchanged although the relative position of the + or correct stimulus varies from right to left.

This represents the first specific control for $\odot 28+ - \odot 7+$ discrimination after a varying amount of preliminary training had been completed. If a chick could not react correctly under these conditions, it was assumed that the preliminary training

² In test 5, the source distances were equal and no controls were introduced.

had not been completed. If the previous correct reactions were not noticeably interrupted by this control system, the chick was considered ready for a larger variable. With the exception of the records for chicks 3, 6, and 7 the essentials of this procedure were carried out for every record given in table 3. The results presented in tabular form, therefore, are those of controls; they are not training or learning records.

The significance of having the +compartment darker than the -compartment in most of the tests of this control series appears when the plan of the preliminary training is set forth. In the beginning, the chick was required to choose on the basis of a visual complex consisting of (1) the lighter compartment in which the stimulus area was (2) larger, (3) triangular, and (4) brighter. As soon as consistent choices appeared, the inequalities between the two stimuli, except size difference, were gradually removed by replacing the triangle with a circle, increasing the upper illumination, and gradually bringing the source lamps to an equal distance from the diffusing or display surfaces. Next, the source distances were gradually and irregularly made unequal. Possibility of discriminating on the basis of brightness and luminous intensity, or either, was thus eliminated before reaching the final control stage. In the more thoroughgoing control series, therefore, the most important fact to establish was certainty about the possibility of general illumination. The +compartment was thus made darker after the first two tests while the other variations were continued. In the matter of general illumination, then, the conditions of the final controls were exactly reversed from those of the preceding training series.

This method of preliminary training was adopted after the perplexing experience with chick 3, described in Chapter IV, and the discovery of the crack which admitted reflected light. The incident suggested that the chick which was being trained, preliminary to the primary threshold study, should be aided in this early stage by having the differences between the two visual stimuli emphasized by a combination of light factors.³ Two stimulus areas, differing from each other with respect to one quality only, present to the chick a problem which is quite

³ Yerkes, R. M. The discrimination method. *Journal Animal Behavior*, vol. 2, p. 142.

unnatural. Under natural conditions, it probably relies upon combinations of many visual factors. The perception of an isolated visual quality is a technical human problem, not a natural animal problem.

Johnson⁴ criticises the use of the visual complex in preliminary training on the ground that one is risking a large waste of time. He says:

It has happened that an experimenter discovers after several weeks of training that the animal had learned to react to difference of e.g. brightness, and had not been affected by the other stimulus-differences. It would seem that a difference in luminous intensity is especially objectionable since in dark surroundings the animal can choose the brighter or darker alley without attending specifically to the stimulus-forms.

Now the value of the visual complex lies precisely in the fact that the natural inclination of an animal is to attend to some other factor than the one under investigation. A discrimination habit is hastened because the animal may resort to the most conspicuous cue. Whatever this cue may be, it is used as a valuable ally in directing the animal's attention to the proper detail. A patient and alert experimenter can eliminate brightness, luminous intensity, et cetera so gradually that the animal's basis of discrimination is quite simply switched to the detail in question, provided that the detail is perceivable for the animal. The change should not be made abruptly, nor is it necessary to wait for a perfect habit. Slight changes should be commenced as soon as there is evidence of an incipient habit. My results with chick 3, in contrast with later results from other chicks, compel me to favor the use of the visual complex in preliminary training. The success of one method or another evidently depends to a great extent upon the temperament of the experimenter.

Coburn's study (6, Chapter 2) of the vision of the crow furnishes the only available results on size perception in birds that are comparable with my results. His study of the crow's perception of size was not primarily a threshold study, but his preliminary results roughly indicate in centimeters a 3-2, 5-3, 6-4, and 9-6 discrimination of circles. A hasty series of tests towards the close of his observations indicate a discrimination between a 5 cm. circle and a 4.5 cm. circle. He thinks a finished

⁴ *Journal Animal Behavior*, vol. 4, p. 324.

threshold study would reveal a discrimination considerably smaller than a 0.5 cm. difference.

Evidently the crow's perception of size is much superior to the ability of the chick in the same task. Although the experimental setting was somewhat different in our studies, it seems that they are sufficiently alike to warrant comparisons. The maximum variable that my chicks were able to discriminate from a standard 6 cm. circle was the same, 4.5 cm. circle, as his crows discriminated from a 5 cm. circle. From the standpoint of size perception, it would seem, therefore, that the ability of the crow is considerably greater than that of the chick.

CHAPTER VI

FORM PERCEPTION

The development of a definite procedure in the study of form perception in the chick followed, in general, that which has been described in the preceding chapter on size perception. A study of the ability of the chick to discriminate between circles and triangles which are equal in area was made with two of the second group, chicks 9 and 11. The latter became afflicted with "leg weakness" after the 24th series, up to which time it had given no positive results. The results from chick 9 which are presented in table 6 might be regarded as slightly positive.

On the whole, the number of choices of the circle, as shown in table 6, indicate some sort of discrimination. Series 10 was perfect. Series 25 contains 9 correct choices and several series reached 70 per cent or 80 per cent correctness. It is not surprising that the chick became discouraged before a perfect habit was established, for the plan of starting with complex stimuli and working towards the single detail had not yet been adopted. A system of control similar to that described in the preceding chapter was followed throughout the work. The surprising feature is the high percentage of "right" choices on January 4 and 5 when the chick was becoming discouraged and frightened. This discouragement resulted in a rush for one stimulus or the other as though "to get the choice over." It appears that there was some sort of a difference between the two illuminations which tended to attract the rushing chick, but this was not clearly enough perceived for a dependable basis of response. But even though a discrimination between the stimuli be admitted, it does not follow that the chick perceived form. As has been pointed out in Chapter II, the distribution of light on, or the unequal stimulation of, the different parts of the retina may have been the discriminable basis.

The result of this experience with chick 9 convinced me that a better method was necessary to determine with certainty whether the chick actually perceives form. When the study

of form perception was begun with group 3, therefore, the method of the preliminary visual complex was adopted. That is, form, in the beginning, was made only one of other visual factors which were gradually eliminated as the experiment progressed. Only one chick, No. 21, gave anything like positive results. The work with this chick, including considerable train-

TABLE 6
Form Perception: $\odot$ 28+ — $\triangle$ 28+
No. 9. Hatched: December 1, 1911. Sex: ♀

SERIES	DATE	RIGHT	WRONG	TIME
1	Dec. 9	4	6	
2	11	8	2	44.2
3	12	5	5	47.1
4	13	6	4	49.2
5	14	7	3	24.8
6	15	6	4	54.6
7	16	6	4	28.3
8	18	4	6	56.8
9	19	5	5	15.9
10	19	10	0	29.5
11	20	6	4	60.2
12	21	8	2	16.7
13	22	7	3	42.7
14	23	5	5	32.8
15	25	6	4	29.5
16	26	8	2	24.2
17	27	7	3	42.8
18	27	4	6	32.8
19	28	4	6	44.7
20	28	6	4	33.2
21	28	5	5	22.0
22	29	3	7	29.3
23	29	6	4	13.3
24	30	7	3	12.7
25	Jan. 2	9	1	27.8
1	2	7	3	30.9
2	3	5	5	25.4
3	4	7	3	12.5
4	5	8	2	4.6 (Rushing)
5	6	(Discouraged; rushed blindly and wildly towards either stimulus)		

ing in size and brightness vision, represents more than 1500 tests.

The experiment on form discrimination with chick 21 may be divided into three parts: (1) A preliminary investigation; (2) reactions to the triangle-circle; and (3) reactions to the circle-triangle. The method of the visual complex and the general improvement of my technique enabled me to get much more

work out of this subject, and at the same time, called forth less energy than in the earlier tests. No. 21 knew me quite well by this time. It was perfectly contented to leave its companions in the chick-room and go alone with me to the dark-room for work. The chief reason for this was the fact that it always had its morning feeding in the dark-room. As soon as we reached the experiment room it was given a little chick food and allowed to run freely about until the apparatus was made ready for the tests. During the preparation of the apparatus, the chick would follow me about the room (then lighted) twittering and contented, but if it were left alone for a few minutes its dissatisfaction was made known by loud and ceaseless peeping.

When everything was ready the chick was placed in the apparatus. At this point the note in its voice changed to a slightly modified "hovering twitter." Commonly this peculiar sort of "singing" changed, as the chick entered the discrimination chamber, to the "food twitter" which was continued all the time it was inspecting and comparing the two stimulus areas and, of course, after it had entered the nest box, for there it was rewarded by finding a few grains scattered in the litter. In this manner a series could be completed in about fifteen minutes, after which the chick was taken from the experiment box and given more food and its freedom in the room. This procedure could be carried out until the chick's hunger was satisfied after which the tests went so slowly and with such uncertainty that it was found best to postpone the work until the following morning. As the bird became older this mode of experimentation could be carried on as long as three hours.

While I was preparing test sheets or making notes at my desk between experiments, No. 21 would crowd about my feet and "beg" to be taken up. If it were allowed to perch itself on my arm it would sit there as long as I was quiet, contentedly preening its feathers and occasionally giving a short "hovering twitter." All of this indicates that the chick was quite contented and normal throughout the experiment.

Table 7 shows the results of my first study of form with chick 21 in which it was trained to go to the triangle and to reject the circle or square. While none of the results here recorded are clear cut, there is strong evidence that the chick was discriminating between the two stimuli. This experiment was hurried

lest the chick should not remain in good physical condition, but at its conclusion the bird was in excellent health, having out of doors range, so the work was repeated with more thoroughness.

The last two series (24 and 25) of table 7 were introduced as a different sort of control tests. The circle was larger than the triangle, hence it afforded an opportunity to see if the chick would react to form difference, after this training, rather than size difference. Apparently it was demanding too much of the chick for it became discouraged at this point and the training had to be repeated.

TABLE 7
Form Perception
No. 21. Hatched: February 9, 1912. Sex: ♀

DISCRIMINATION	SERIES	DATE	RIGHT	WRONG	TIME
△ 28+ — ○ 7+	6	March 13	7	3	10"
" — ○ 12+	7	" 13	9	1	11
" — ○ 15+	8	" 14	8	2	18
" — ○ 19+	9	" 14	4	6	12
" — "	10	" 14	6	4	8
" — "	11	" 14	8	2	33
" — "	12	" 14	8	2	12
" — "	13	" 14	8	2	12
" — "	14	" 14	8	2	12
" — ○ 23+	15	" 14	8	2	13
" — "	16	" 15	8	2	6
" — ○ 24+	17	" 15	8	2	13
" — ○ 25+	18	" 15	9	1	6
" — ○ 26+	19	" 15	6	4	17
" — ○ 27+	20	" 15	8	2	18
" — ○ 28+	21	" 15	7	3	17
" — "	22	" 16	9	1	8
" — □ 28+	23	" 16	9	1	40
" — ○ 63+	24	" 18	6	4	56
" — "	25	" 18	6	4	85

In table 8 are presented the results of the re-training of No. 21. While the record, as shown in the table, indicates that the chick discriminated between the triangle and the circle, it is, nevertheless, equally convincing that the chick did not perceive the form difference. It had reacted properly to the △ 28+ — ○ 19+ and — 23+ when the apex of the triangle was at the top, but when the triangle was inverted (series 20, March 25), the animal did not choose the triangle more than half of the time. With the triangle again upright, the correct reactions returned. Proper responses were made when the

areas were equal (series 8 and 9, March 28), but when the inscribed triangle was substituted for the standard, the chick was again confused. Series 13, (March 29), another control where the triangle was inverted, gave more decided negative results which were immediately preceded and followed by almost perfect reactions. As a further test of inverting the triangle, the inversion was made during a regular series, 15, (March 30). The result of the inversion during tests 5-7 was one right choice out of three chances with an average time of

TEST SHEET

Title of investigation, Form: $\Delta 28+ - \circ 63+$
 Experimented on, 21
 Harvard Psychological Laboratory, March 18, 1912
 Record Sheet, 2; Series, 24

TEST	BEHAVIOR	RECORD
1 l	$/// - \overline{///} + \overline{///} \circ - \overline{///} + ///_a$	0-65
2 r	$/// + ///_a$	0-7
3 l	$/// - \overline{///} \Delta^1 + ///_a$	E-1-14
4 l	$/// - /// + // \backslash + ///_a$	0-14
5 l	$/// - /// \Delta^1 \overline{////} + ///_a$	E-1-55
6 r	$/// - + /// \overline{////} - /// \circ + // - \overline{///} + \overline{////} - \Delta^2 +_a$	E-2-171
7 r	$/// + // - // + // + \overline{////} + // - \overline{////} + ///_a$	0-94
8 r	$// + // \backslash - // \overline{\\} \overline{////} + //_a$	0-69
9 l	$/// + ///_a$	0-4
10 r	$/// - / \circ + \overline{\\} - / + / \overline{////} - // \Delta^1 + //_a$	E-1-70

6-4-56.3

39 seconds. These three special tests were preceded and followed, during the same series, with *perfect* reactions (triangle upright) the average time of which was somewhat *less than one-sixth* of the average time for the special tests.

In connection with these results, the details of the behavior of No. 21 are presented when it was confronted with $\Delta 28+ - \circ 63+$ stimuli. These tests are reported in table 7 as series 24 and 25. The test sheets show how utterly confusing to the chick was this condition. The results of this test were verified

in series 10 recorded in table 8 under date of March 28 where the record is the same and the behavior was very similar.

Finally this chick's response to the circle-triangle was tested. The reversion of the condition for discrimination was at first confusing to the chick, and much patience on the part of the

TABLE 8
Form perception: Δ 28+ — $\circ$ 28+
No. 21. Hatched: February 9, 1912. Sex: ♀

DISCRIMINATION	SERIES	DATE	RIGHT	WRONG	TIME
Δ 28+ — $\circ$ 9+	9	March 20	10	0	6
" — $\circ$ 12+	10	" 20	10	0	14
" — $\circ$ 15+ (inscription of triangle)	11	" 21	9	1	9
" — "	12	" 21	10	0	9
" — "	13	" 21	10	0	8
" — "	14	" 22	10	0	6
" — $\circ$ 19+	15	" 22	5	5	15
" — "	16	" 23	9	1	6
" — "	17	" 23	10	0	6
" — $\circ$ 23+	18	" 23	9	1	7
" — "	19	" 25	9	1	20
∇ 28+ (inverted) — $\circ$ 23+	20	" 25	5	5	92
Δ 28+ (upright) — $\circ$ 23+	21	" 25	8	2	20
" — $\circ$ 23+	22	" 26	10	0	17
" — $\circ$ 25+	23	" 26	10	0	12
" — $\circ$ 27+	24	" 26	8	2	12
" — "	25	" 26	9	1	6
" — "	5	" 27	8	2	35
" — "	6	" 27	6	4	8
" — $\circ$ 28+	7	" 27	8	2	9
" — "	8	" 28	10	0	5
" — "	9	" 28	10	0	9
Δ 11+ (inscribed) — $\circ$ 28+	10	" 28	6	4	40
Δ 28+ — $\circ$ 28+	11	" 28	10	0	15
" — "	12	" 29	9	1	5
∇ 28+ (inverted) — $\circ$ 28+	13	" 29	2	5	83
Δ 28+ (upright) — $\circ$ 28+	14	" 29	9	1	7
" — $\circ$ 28+	15 ¹	" 30	7	0	6
" — $\circ$ "	16	" 30	9	1	7
" — $\circ$ "	17	" 30	10	0	24
" — $\circ$ "	18	April 1	10	0	15

¹ In series 15 the triangle was inverted during tests 5-7; the result was 2 wrong choices with an average time of 39 seconds.

experimenter was necessary. The plan now was to begin with $\circ$ 63+ — Δ 28+ and gradually to eliminate the size difference by substituting successively smaller circles. In this case the correct stimulus area was the variable and the standard was the sign of "shock" and "no escape." From the summary of these

results, table 9, the early records are omitted since these tests were made only as a means of getting a discrimination between the later forms. The size of the circle was gradually decreased from $\circ 63+$ to $\circ 38+$ at which point the tabulation begins. About 400 tests between April 1st and 20th were necessary to bring the chick to the point in its training at which the records of the table commence.

Table 9 shows that the chick was able to acquire the circle-triangle habit. The plan of controlling the qualities other than

TEST SHEET

Title of investigation, Form: $\Delta 28+ - \circ 63+$
 Experimented on, 21
 Harvard Psychological Laboratory, March 18, 1912
 Record Sheet, 2; Series, 25

TEST	BEHAVIOR	RECORD
1 r	$/// + // - /// \circ \backslash \backslash - \overline{//} + \overline{//} - \overline{//} \circ + \overline{//} \overline{\circ} - / \Delta^0 + // \text{a}$	E-0-145
2 r	$/// + \overline{//} \overline{\circ} \overline{\text{a}} - /// + \overline{//} \overline{\circ} - // \circ + /// \text{a}$	0-79
3 r	$/// + - \circ + // \overline{\circ} \overline{\text{a}} + /// \text{a}$	0-45
4 r	$/// \circ + /// \overline{\circ} \overline{\text{a}} - / + \overline{//} \overline{\text{a}} + /// \text{a}$	0-60
5 l	$/// \circ - // + /// \div /// \overline{\text{a}} + /// - // \Delta^1 + /// \text{a}$	E-1-61
6 l	$// + /// - \overline{//} \overline{\circ} \overline{\text{a}} + /// \text{a}$	0-33
7 l	$// + // - /// \overline{\text{a}} - /// \overline{\circ} - // + /// \text{a}$	0-46
8 l	$/// + /// - \overline{\circ} \overline{\text{a}} + / - /// \Delta^1 + /// \text{a}$	E-1-35
9 r	$/// - /// \circ \overline{\text{a}} - // \overline{\text{a}} + /// \text{a}$	0-99
10 l	$/ - \overline{//} \overline{\text{a}} - \Delta^0 \overline{\text{a}} - \Delta^0 \overline{\text{a}} - \Delta^1 + \text{a}$	E-1-243

6-4-84.6

form was carried out as heretofore explained. After No. 21 had acquired the $\circ 28+ - \Delta 28+$ reaction, the order shown in the table was followed to determine whether or not the bird actually depended upon form difference. If it had a perception of form such as has been found to exist for size, then no marked change in the results should have occurred when $\circ 28+$ was replaced by a circle that circumscribed or inscribed the standard

triangle; and if the chick perceived three-sidedness or triangularity on the one hand and circularity on the other hand, there should have been no important modification of its reaction when the triangle was inverted.

TABLE 9
Form perception: $\odot 28+ - \triangle 28+$ and $\odot 28+ - \square 28+$
No. 21. Hatched: February 9, 1912. Sex: ♀

DISCRIMINATION	SERIES	DATE	RIGHT	WRONG	TIME
$\odot 38+ - \triangle 28+$	12	April 20	10	0	4
$\odot 33+ - "$	13	" 20	6	4	7
" — "	14	" 20	5	5	7
" — "	15	" 20	7	3	5
" — "	16	" 20	8	2	8
" — "	17	" 20	6	4	6
" — "	18	" 20	10	0	8
$\odot 28+ - "$	19	" 20	10	0	5
$\odot 44+ - "$	20	" 20	10	0	5
" — $\nabla 28+ (\triangle \text{ inverted})$	21	" 20	9	1	5
$\odot 28+ - \triangle 28+ (\triangle \text{ upright})$	22	" 21	5	5	6
" — "	23	" 21	6	4	4
" — "	24	" 21	6	4	7
" — "	25	" 21	3	7	6
$\odot 33+ - "$	1	" 21	10	0	4
" — "	2	" 21	10	0	4
$\odot 28+ - "$	3	" 21	10	0	5
" — $\nabla 28+ (\triangle \text{ inverted})$	4	" 21	6	4	5
$\odot 15+ - \triangle 28+ (\odot \text{ inscribed})$	5	" 21	4	6	11
$\odot 28+ - "$	6	" 22	8	2	10
" — "	7	" 22	8	2	7
" — "	8	" 22	10	0	6
" — "	9	" 23	8	2	5
" — "	10	" 23	8	2	5
" — "	11	" 23	9	1	4
" — "	12	" 23	9	1	7
" — "	13	" 24	9	1	5
" — "	14	" 24	9	1	4
" — $\square 28+$	16	" 24	5	5	5
" — "	17	" 24	5	5	3
" — "	18	" 25	3	7	4
" — "	19	" 25	6	4	4
" — "	20	" 25	5	5	6
" — "	21	" 25	8	2	6
" — "	22	" 25	5	5	4

The work on form thus indicated that the chick can discriminate between circles and triangles of equal area, and there are indications of a discrimination between circles and squares of equal area (witness series 21, April 25, table 9, and series 23, March 16, table 7), but with the application of control tests we have indications that this discrimination is on some basis

other than form. The results from the inversion of the triangle indicate that the basis of choice depends upon the unequal stimulation of different parts of the retina. When the extended base of the triangle is so placed as to stimulate the region of the retina which was formerly stimulated by the apex of the triangle, the chick becomes confused. Under the conditions of the present experiment, therefore, I am forced to conclude that the apparent reactions to forms are the result of keen perception of relative size differences.

The image formed on the retina of the chick is truly changed when the triangle is inverted by causing certain particular size reversals. The vertex, which was formerly uppermost, becomes interchanged with the base. The portion of the retina which was formerly stimulated by an extended line of light relative to the base of the triangle becomes stimulated by a mere point of light which is related to the vertex of the triangle. Inversion thus causes particular changes in the extension of the stimulated portions of the retina. It would seem, therefore, that the inversion of the triangle, though causing no change in form as such, produces these relative size differences which were evidently a source of confusion to the chick.

This control of inverting the triangle is a severe test, but it affords an excellent basis of comparison between the chick and other birds. Coburn made the same test with his crows without interrupting their correct choices. It therefore seems to be a legitimate and highly desirable procedure in form studies. In addition to circle-triangle discrimination, Coburn's crows discriminated a circle from squares and hexagons.

Coburn's crow study again furnishes from the birds the only results directly comparable with my chick results. Porter tried to study the perception of forms and designs in sparrows by using six form boxes made of poplar boards. He secured negative results but his method was weak. His birds were free to approach all of the boxes in one of which there was always food. There was no strong incentive for the bird to seek the correct box first because it was ultimately rewarded with food regardless of its first approach. Even had the results been positive nothing definite could have been asserted about the detail vision of the birds on account of the lack of any system of control.

Porter finds that the sparrow and cowbird can discriminate three horizontal lines or a black diamond from a blank card or from each other. No more weight can be attached to these results than could be given to his efforts to study form perception. On account of the widely differing method and apparatus a comparison of Porter's results with my own would be quite out of place.

The chick, then appears inferior to the crow in the matter of form perception. Where the crow appears to react by means of a relative form difference, the chick reacts to a circle-triangle situation on the basis of a specific form, or shape, difference. Responses to this specific form relation are much less readily acquired by the chick than responses to size differences.

CHAPTER VII

FLICKER PERCEPTION

Inasmuch as the preceding studies with the chick indicated unequal visual sensitiveness to the spatial details of size and form, there arose the question of the importance of the rôle played by moving stimuli in the chick's vision. Movement, indicating danger or food, certainly is of great daily importance to the seeing animal. The remarkable ability of birds to discover worms has been plausibly attributed to the visual perception of movement. Might not the chick, then, demonstrate greater perceptual ability if a problem were presented demanding reactions to moving stimuli instead of stationary spatial differences?

To test the chick's sensitiveness to movement, the same dark room-discrimination method was employed. The stimuli presented were two 6 cm. circular openings illuminated as in the preceding experiments. The sources of these illuminations, however, were attached to an interrupting device by means of which the lights could be made to flash at different, though regular, intervals. The positive rate was adopted as once per second. The negative stimulus was a similar illumination flashing more rapidly.

To produce these interruptions a rotating disc of wood, one inch thick and four inches in diameter, was used. Bearing upon the circumference of the disc were two pairs of brass points, each pair being in the circuit of one of the source lamps. When one of these pairs of points bore upon a conducting surface, the circuit was complete; when it bore upon a non-conductor, the circuit was broken. The interruptions of the sources of illumination, then, depended upon an alternation, on the circumference of the disc, between a conductor and an insulator.

The wooden surface itself provided the insulation. For the conduction, thin bands of brass were firmly fitted and screwed to the circumference of the disc. Thus, a brass band extending half way around the circumference of the rotating disc would provide a complete circuit half of the time. In other words, the lamp depending for its illumination upon this band of brass would flash

off and on at regular intervals and the *on* interval would equal the *off* interval.

The brass points were grouped so that one pair bore upon the left, the other upon the right edge of the circumference of the disc. By attaching to the right edge, for example, a single band of brass equal to half the circumference of the disc, and to the left edge two bands of brass each equal to one-fourth of the circumference, the

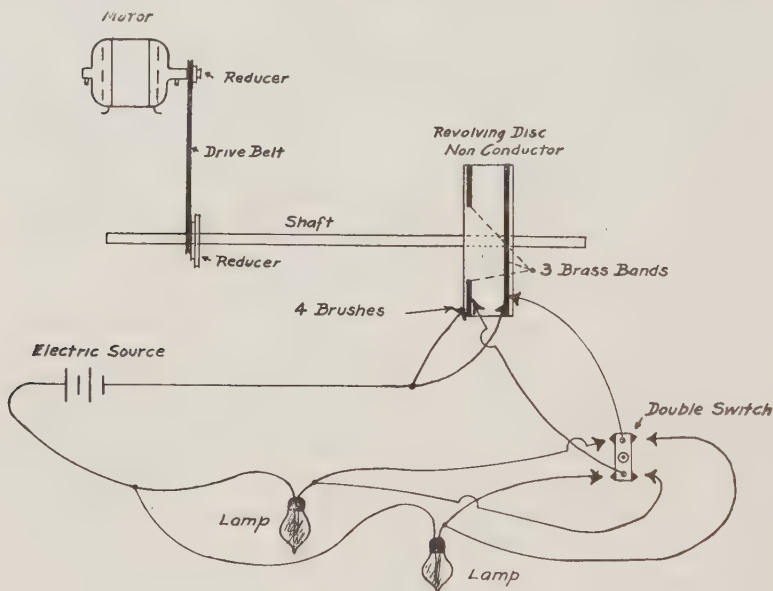


FIG. 7

Flicker apparatus. Schematic diagram showing how flicker stimuli were produced. The lamps were mounted on the movable carriages in the same source compartments described in Chapter III. By means of the double switch shown in the wiring scheme it was possible to alternate between the two lamps the slow and rapid flashes. The revolving disk is illustrated in this figure as much too large when compared with the illustration of the motor. The worm gear reducer, described in the text, is not shown in the illustration.

lamp connected through the right pair of points would have *on* and *off* intervals twice as long as the intervals of the other lamp. But, for any period of time, the total of the *on* or *off* time of the one lamp would equal the same of the other lamp. Similarly, the *on* and *off* flashes of the one lamp could be divided so that the intervals were one-third or one-fourth of the intervals of the other lamp.

A double switch was inserted in the connections so that the relative locations of the slow and rapid flashes could be reversed. The disc was driven by an "A.C." motor having a commercial rating of one-eighth horse power and twelve hundred revolutions per minute. The excessive speed was cut down by means of a worm gear reducer so that the rotation rate of the disc in most of the training tests was approximately once per second. The lamp interrupted by a single insulation, therefore, flashed *on* and *off* once every second. The rate was noted by recording with a stop watch the time elapsing during 50 flashes. Practically no variations were observable during the experiment.

Three driving pulleys of different sizes on the motor and three on the reducer made possible nine different speeds ranging between 50 revolutions of the disc in 162 seconds and 50 revolutions in 39 seconds. The rate of flashing, however, was increased two or more times depending upon the number of breaks on the circumference of the disc.

There is a definite objection to this method of measuring the interruptions, but for the present purpose, rough tests indicate that it may be ignored. Since each *on* interval heats the filament of the illuminating lamp, there is a tendency for the illuminated interval to last longer than the dark interval, and as the alternating intervals become shorter there would be a tendency for the total time of illumination to become greater than the total time of darkness. Yet it seems justifiable to ignore this possibility since the number of alternations is unchanged. Moreover, the glow of a filament after the "flash-off" seemed to be completely swallowed up by the opal flashed glass which served as a diffusing surface. It was also found that the tungsten lamps responded quite promptly to the off and on contacts and more promptly than the carbon lamps.

The training was begun with a one-three discrimination difference. The chick was trained to choose the slower rate. As in the spatial tests, a visual complex consisting of greater brightness added to the slower stimulus was presented at first and gradually changed to the single detail of flicker. Control of the luminous flux was gradually introduced by means of the upper illumination, and, in a few tests, by an additional 2 c.p. lamp located at the middle of the rear of the experiment box. Further controls were made after the habit became established, by irregularly varying

the source distances within a maximum of 40 cm., and by irregularly changing the shifter from left to right.

Chick 27 learned the problem so much more rapidly than the other subjects that it was evidently ready for the one-two relation before the others had acquired the one-three habit. In view of the possibility of the inequality in the two stimuli of the dark-light alternations, it was deemed desirable to reduce the difference rates towards the threshold. This would not only indicate the chick's threshold of difference, but also make less the possibility of different light-dark ratios serving as the basis of discrimination. Since early experience had emphasized the importance of concentrating the work as much as possible while the chicks were in satisfactory condition, further work with the other chicks was abandoned and the mechanism was changed for one-two discrimination. The change seems to have been fortunate, for the other chicks dropped off shortly, and chick 27 did not last long enough to complete more than an elementary phase of this particular task.

The details of the learning of this task by chick 27 are furnished in Chapter VIII where tables 15 and 16 present quantitatively several phases of behavior in addition to the criterion of correct choice per series of ten tests. Table 10 presents the discrimination conditions, reactions of the chick, and the controls employed.

To determine the specific rates of the two stimuli, the method was adopted of recording with a stopwatch the time elapsing during fifty flashes of either stimulus. Thus the time relation is given as 1-3 or 39'' - 13'' for the first twenty series. In series 21 the same relative rate was continued, 1-3, but the specific rates were made slower, the time for 50 flashes being respectively 54 and 18 seconds. The next change, introduced in series 30, January 10th, results in both relative and specific variation. The flicker relation becomes 1-2 and the respective periods for 50 flashes are 36 and 18 seconds. Slight changes were made in series 31, and in series 32 the effect of substituting without additional training, 80-40 and 20-10 periods was observed.

At the close of series 20, the controls had become rigorous enough to indicate that the flicker difference, or some aspect of it, was really perceived. On January 8, at the close of the 26th series, an unusually severe control was introduced. The upper lamp was changed from a 4 c.p. to a 16 c.p. illumination, and in addition,

TABLE 10
Flicker Perception
 No. 27. Hatched: December 14, 1916. Sex: ♀

SERIES	TIME RELATION	+ RE- SPONSES	TIME	REMARKS	DATE
A	1-3 = 39'' - 13'' for 50 flashes	—	—	Preliminary; no regular procedure.	1915 12/21
B	"	—	—	Ibid.	12/22
1	"	5	70''	Ibid.	12/23
2	"	6	91	Ibid.	12/25
3	"	9	72	+ source 50; —, 250	12/27
4	"	5	15	+, 70; —, 230. Time taken from start to choice. Weak shock.	
5	"	7	3	+, 80; —, 220.	12/29
6	"	6	3	+, 100; —, 200.	12/29
7	"	7	4	+, 120; —, 200.	12/29
8	"	7	7	+, 130; —, 200.	12/30
9	"	4	?		12/31
10	"	9	16		12/31
11	"	8	15		1/1/16
12	"	5	23		1/1
13	"	8	17	+, 160; —, 200	1/1
14	"	7	15	Irregular variation between 150 and 200.	1/1
15	"	9	11	Ibid.	1/3
16	"	6	12	Right, 160; left, 200.	1/3
17	"	5	8	Right, 200; left, 160.	1/3
18	"	8	22	Right, 160; left, 200.	1/4
19	"	10	23	Ibid.	1/4
20	"	10	65	Right, 200; left, 160. Upper illumination.	1/5
21	1-3 = 54'' - 18'' for 50 flashes	7	14	Ibid. First 5 choices correct; time 12''.	1/5
22	"	6	33	Irregular variation. Upper illumination.	1/6
23	"	10	7	Ibid.	1/6
24	"	8	53	Ibid.	1/7
25	"	10	44	Right, 160; left, 200.	1/7
26 (1)	"	10	51	Right, 200; left, 160.	1/8
27 (2)	"	8	85	Upper illumination increased from 4 to 16 c.p. 4 c.p. lamp at top of middle of rear end of discrimination box. Errors in tests 3 and 10.	1/8
28 (3)	"	8	16	Ibid.	1/8
29 (4)	"	10	24	Rear light removed	1/10
30 (5)	1-2 = 36'' - 18'' for 50 flashes	7	14	Ibid. Errors in 3, 6, 7.	1/10
31 (6)	1-2 = 40'' - 20'' for 50 flashes	10	22	Ibid.	1/12
*32 (7)	"				
33 (8)	"	9	11	Ibid.	1/13
34 (9)	"	9	22	Ibid.	1/14
35 (10)	"	9	10	Ibid.	1/15
36 (11)	"	9	8	Ibid.	1/17
37 (12)	"	10	10	Ibid.	1/17
38 (13)	"	10	13	Ibid.	1/18
39 (14)	"	8	5	Ibid. Physically weak.	1/20
40 (15)	"	9	4	Ibid. " "	1/20

* Tests for specific or relative stimulus difference; see table 17, page 99, and accompanying text. The tests of series 32 (7) for evidence of relativity or specificity were distributed among the tests of subsequent series.

a 4 c.p. lamp was placed at the rear of the reaction chamber. This combination of illuminations made the experiment box quite light. The novelty interfered considerably as is indicated by the rise in the chick's time for choosing. Out of the entire series, however, the chick made eight correct choices.

Although the ultimate choices were not seriously affected by this introduction of novel conditions, the behavior of the chick was considerably modified. In the now relatively light reaction chamber there was considerable pecking and searching for food. Two or three attempts to jump out of the box were made. The error in test 3 apparently resulted from this pecking and meandering which continued longer than in the two preceding tests. Finally, the chick seemed completely to lose its orientation, for it searched the rear portion of the reaction chamber as much as the forward portion and entered the starting chamber once. The entrance into the wrong compartment was very similar to the entrance into the starting chamber. It did not appear as a definite choice and the chick was not shocked. In the beginning of the test, two careful approaches were made to the + compartment and the - compartment was apparently ignored. Then followed this random wandering, jumping, and pecking during which the chick seemed to lose its orientation.

The choices and behavior of chick 27 indicate that it was able to discriminate in this series of January 8th. The error in the last test of the series was apparently due to carelessness. The ten tests were made within forty-five minutes and only two hours earlier a series had been completed. The chick was "full" and probably had no vivid memory of punishment on account of its high percentage of correctness in past records. Carelessness would be wholly natural at this stage of the work.

Even though it be conceded that the discrimination was satisfactory, there is another point in the behavior which I regard as having greater significance. In the detailed records (unpublished) of behavior in this series, it appears that chick 27 made an unusually large number of approaches to the edge of the electric compartments before venturing in. In addition to this, it "peeked over" towards the exit frequently tossing the head up as though looking at the top of, or over, the door. This suggested that the chick was relying upon the flux of light, for under the cross bar over the forward end of the experiment box, the additional illumi-

nations left a faint shadow which was regularly interrupted by the flashing stimuli. This resulted in a slight but regular alternation of light and shadow on the side of the electric compartments immediately above the exits. The interruption on each side, of course, depends upon the rate of its respective source. This indicates that the interruption of the flux was the basis of the flicker discrimination.

It thus appears that the chick readily discriminates, on some basis, at least a one-two flicker difference. These preliminary results convince me that here is a most promising field of investigation, especially with birds. Interrupted illuminations seem to have high stimulating value, making it relatively easy to direct the attention of the subject to the movement detail. With such stimuli the amount of aimless wandering seems to be considerably less than that which occurs with size and form stimuli.

It is hazardous to compare results obtained in this study from spatial and moving stimuli on account of the improvement in technique which clearly occurred during early stages of the investigation. Since flicker perception represents the last stage of the study it is possible, yet doubtful, that indications of increased responsiveness to moving stimuli are due to improvement in experimental technique. Possibility of individual differences should not be overlooked because objective data on flicker perception have been obtained from a single subject. Moreover, it is not possible to analyze satisfactorily the visual factors that were operative in the intermittent stimuli which were discriminated. On the other hand, subjective judgments support these preliminary data. It seems probable that we shall find the chick, and possibly the birds, more responsive to movement than to spatial factors. At any rate, these results indicate further possibilities of experimentation in animal behavior which ought to receive consideration.

CHAPTER VIII

PROBLEM LEARNING

1. *Analysis of the problem*

The problem which the chick is expected to solve in the experiments that have been described in the preceding chapters may be regarded, for present purposes as divided into two separate tasks. The first task, learning the experiment box, is really a maze problem. The experiment box with its entrance box, discrimination chamber, electric compartments, exits, and nest boxes—is only one of various types of maze. The types of maze, commonly regarded as such, provide, more or less frequently, choices between *open* and *blind* passage ways. These open or closed passages are also present in the experiment box, but the two courses are permanent in the maze proper whereas the corresponding courses in the experiment box are interchangeable.

The principle of interchanging the open and closed passages of the experiment box demands the simultaneous display of two different stimuli, one signifying “this way out” and the other “exit closed.” With the introduction of these two differentiating stimuli, there appears for the animal the second task of “interpreting the signs.” Before the experimenter can study the animal’s ability to interpret these signs—the power of distinguishing, for example, a 5 cm. square from a 3 cm. square or a circle from a triangle—it is necessary that the animal should have learned the principle of the experiment box or maze problem. The solution of this maze problem provides opportunity for noting the animal’s method of forming habits.

As a matter of economy, the experimenter naturally presents the signs of “exit” and “closed” in appropriate relation to the course which the animal is required to follow in learning the initial maze task. The positive (+) sign meaning “exit” is displayed at the beginning of the training series in significant connection with the course prescribed for the animal to reach the nest box. Similarly, the negative (–) sign meaning “closed” appears contiguously with the forbidden nest box. With the exception of two preliminary or

preference series, such a procedure was followed while the chick's learning was being studied. The two phases of the general discrimination problem, therefore, cannot be sharply separated, but throughout the present chapter they will be regarded as distinct, and referred to as the *primary* and *secondary* tasks in the formation of the discrimination habit.

2. *Individual characteristics*

On December 21, work was started upon a problem in flicker discrimination with five chicks belonging to the fourth group. The chicks were at that time approximately one week old. The present remarks will be confined chiefly to three individuals, chicks 24 ♀, 25 ♀, and 27 ♀. The other two chicks shortly succumbed to the confinement of the laboratory. No. 24 was characterized in my notes as rugged and next in size to No. 25. No. 25, a White Plymouth Rock, remained from the first robust and oversized.¹ No. 27 was somewhat undersized. Chicks 24 and 27 were Barred Plymouth Rocks.

On the first day each of the chicks was allowed to escape ten times at either exit. This was the first preliminary series. The positive stimulus was displayed first at the left, and thereafter alternately at the right and the left. Six tests were made in the morning and four in the afternoon. During the morning tests the exits were wide open. In the seventh test, the doors were nearly closed and thereafter were completely closed. In the eighth, ninth, and tenth tests and in the series following, the door of the exit was opened as soon as the chick had chosen the compartment.

On December 22, the second preliminary series was similarly started. Four tests were given in the morning, three in the afternoon, and the remaining three in the morning of the following day. In these two preliminary series, no preference for either of the stimuli was noticeable. Table 11 summarizes the choices with reference to the stimuli which, in subsequent training, became plus (+) and minus (−) signs. The table indicates that there was no preference for either stimulus.

Certain right or left preferences, on the other hand, are to be found. Table 12 summarizes these tendencies. No. 27 shows a distinct preference for the left side but chicks 24 and 25 manifest no preference.

¹In comparison with the chicks of the group.

In view of the fact that No. 27, in the secondary task, shows learning superiority over chicks 24 and 25, these initial preference differences are suggestive. Some of the peculiar types of native behavior manifested by these three chicks appear in table 13. Reference to the table indicates a close similarity between the behavior of chicks 24 and 25 which differs some-

TABLE 11

CHICK	STIMULUS CHOSEN	
	+ Stimulus	- Stimulus
15	11	9
23	11	9
24	9	11
25	10	10
27	12	8

what from the behavior of No. 27. The average time of escape for chicks 24 and 25 during these preliminary series is respectively 8.0 and 8.6 seconds; for No. 27, it is 21.7 seconds or two and one half times as great. Further similarities and differences may be noted in the tendencies of chicks 24 and 25 to waver between choosing the right and left sides, and the tendency of No. 27 to stick persistently, after the first two tests, to left choices with only two variations appearing in tests 10 and 13.

TABLE 12

CHICK	RIGHT CHOICES	LEFT CHOICES
15	13	7
23	15	5
24	10	10
25	10	10
27	4	16

On the other hand, table 13 suggests close similarity among all three chicks with reference to the stimuli. The letter following the number of the test indicates the side on which the + stimulus appeared. The columns headed "choices" show which stimulus and which side was chosen in any test by each individual. As three times is the greatest number of successive + or - choices, it is quite evident that neither of

the stimuli was an original factor determining the choosing. Thus, among the individual native tendencies that may have existed with these different chicks as influences in forming the habits demanded by this problem, the tendency of right or left choosing appears to be most pronounced.

TABLE 13
Preliminary Series

TESTS	NO. 24 ♀		NO. 25 ♀		NO. 27 ♀		DATE
	Choices	Time	Choices	Time	Choices	Time	
1 l	+ l	24	+ l	6	- r	24	12/21 a.m.
2 r	- l	22	- l	25	+ r	61	
3 l	- r	9	+ l	4	+ l	33	
4 r	- l	9	- l	4	- l	12	
5 l	+ l	5	+ l	5	+ l	9	
6 r	- l	4	+ r	5	- l	5	
7 l	- r	4	- r	5	+ l	10	12/21 p.m.
8 r	+ r	6	+ r	31	- l	9	
9 l	- r	7	+ l	9	+ l	6	
10 r	- l	3	+ r	10	+ r	25	
11 r	+ l	6	- l	5	- l	7	12/22 a.m.
12 l	- r	13	- r	10	+ l	26	
13 r	+ r	6	+ r	9	+ r	33	
14 l	- r	4	- r	10	+ l	22	
15 r	- l	3	+ r	7	- l	12	12/22 p.m.
16 l	+ l	7	- r	9	+ l	51	
17 r	+ r	11	- l	4	- l	11	
18 l	+ l	5	+ l	9	+ l	25	12/23 a.m.
19 r	+ r	8	- l	11	- l	26	
20 l	- r	8	- r	7	+ l	27	
Average time		8.0		8.6		21.7	

With the twentieth test the two preliminary series ended and thereafter the training series began. At this point the chicks, instead of being allowed to escape where they chose, were required to escape from the compartment where the + stimulus was displayed. The animals were aided in releasing the tripping device, because they lacked sufficient weight; but the experimenter could not cause a release of the exit door until the chick stood in the proper place, when a pull on the silk line released the tension of the lifting spring so that the

chick's weight released the trip. The chicks readily learned to approach close to the door of the exit which brought them upon the tripping device. As the weight of the growing chicks increased the exit automatically opened when they stepped on the tripping device. The electric shock was not introduced until the fourth training series.

In the first two series of training, the visual stimuli differed with respect only to flicker. This was a period of training during which the chick's task was chiefly to learn the primary problem. Visual discrimination was encouraged at the beginning of the third series by presenting stimuli differing with respect to several factors. This third series may be regarded as transitional between the primary and secondary tasks. It is the last series during which the time record was made from start to exit. In subsequent series the time record represents the number of seconds elapsing between entrance to the discrimination chamber and choice of a compartment. If the choice happened to be wrong (-), therefore, considerable time might subsequently elapse between the choice and the escape, whereas the time elapsing between choice of the + compartment and escape was regularly measurable only in fractions of a second. The maze problem, it was assumed, was sufficiently learned at the end of the third series to permit introduction of the secondary task of discrimination and correct choosing.

For further comparison of the characteristics of the chicks during the preliminary series, table 14 is presented. This table indicates the number of times right or left sides and + or - stimuli were successively chosen throughout the first two preference (preliminary) series. Frequency of change is greater as the number of successive choices of the same side or the same stimulus is smaller. The total number of changes is indicated by the number in the first column which stands on the same line with the last record in any other column. For convenience the total number of changes in choice of sides or stimuli is indicated at the bottom of each column. Persistence in choosing is assumed to be greater as the number of recorded changes is smaller. In other words, the fewer the changes recorded for any individual, the greater is the indication of its persistence in following up a particular line of response.

TABLE 14
Initial Preferences
 Computed from records in the two preliminary series

FREQUENCY OF CHANGE	NO. 24 ♀		NO. 25 ♀		NO. 27 ♀	
	Side	Stimulus	Side	Stimulus	Side	Stimulus
0	l 2	+ 1	l 5	+ 1	r 2	- 1
1	r 1	- 3	r 3	- 1	l 7	+ 2
2	l 3	+ 1	l 1	+ 1	r 1	- 1
3	r 3	- 2	r 1	- 1	l 2	+ 1
4	l 2	+ 1	l 1	+ 2	r 1	- 1
5	r 3	- 2	r 5	- 1	l 7	+ 1
6	l 2	+ 1	l 3	+ 3		- 1
7	r 1	- 1	r 1	- 2		+ 2
8	l 1	+ 1		+ 1		- 1
9	r 2	- 2		- 1		+ 3
10		+ 4		+ 1		- 1
11		- 1		- 2		+ 1
12				+ 1		- 1
13				- 2		+ 1
14						- 1
15						+ 1
Total number of changes	9	11	7	13	5	15

TABLE 14A
Initial Preferences
 Computed from records in first three training series

FREQUENCY OF CHANGE	NO. 24		NO. 25		NO. 27	
	Side	Stimulus	Side	Stimulus	Side	Stimulus
0	r 2	+ 1	r 2	+ 1	l 1	- 2
1	l 1	- 3	l 1	- 3	r 3	+ 1
2	r 3	+ 1	r 3	+ 1	l 4	- 2
3	l 1	- 3	l 2	- 2	r 1	+ 1
4	r 2	+ 3	r 4	+ 2	l 6	- 1
5	l 2	- 1	l 2	- 6	r 2	+ 5
6	r 2	+ 1	r 2	+ 2	l 1	- 2
7	l 2	- 1	l 1	- 2	r 6	+ 2
8	r 2	+ 2	r 1	+ 1	l 2	- 1
9	l 3	- 1	l 1	- 1	r 1	+ 5
10	r 2	+ 1	r 1	+ 1	l 1	- 1
11	l 1	- 2	l 1	- 1	r 1	+ 7
12	r 1	+ 5	r 4	+ 1	l 1	
13	l 1	- 1	l 1	- 1		
14	r 4	+ 1	r 1	+ 5		
15	l 1	- 1	l 1			
16		+ 2	r 1			
17			l 1			
Total number of changes	15	16	17	14	12	11

Table 14a is similarly presented to show evidence of preferences during the first three training series. Perhaps the outstanding feature of the behavior represented in table 14a is the change in preference of No. 27 from side to stimulus. This change is noticeable at the beginning of the third training series when the two flicker stimuli were made more conspicuously different by the addition of other visual differences. With the introduction of a discriminable visual complex there occurred a noticeable change in the behavior of No. 27, indicated by six side changes and only three stimulus changes, whereas the behavior of No. 24 and No. 25 did not noticeably change. As indicated in tables 14 and 14a, No. 27 made comparatively few changes in choice of sides and many changes in choice of stimuli throughout the two preliminary series and the first two training series. From the beginning of the third training series this relative preference for side suddenly ceased and persistence in choosing the + stimulus became dominant. In the last 13 choices recorded for No. 27 in table 14a, only one stimulus choice is - (wrong).²

3. *Quantification of the learning process*

In learning the primary maze task there are certain details of behavior which are fairly measurable. The possibility of quantitatively measuring these constant evidences of learning was suggested when certain gradual changes were observed in the chick's behavior towards the exit. During the preliminary series, while the exits were open, there is little reason for suspecting that the stimuli were of any significance to the chick. After the exits had been closed in these preliminary series, the stimuli became a factor attracting the chicks to the electric compartments but the exit door was opened as soon as the compartment was entered. The new requirement in the training series was to go into the compartment towards one of the stimuli, to turn *outwards* at the furthest end of the electric compartment, and to step upon the tripping device close to the unopened exit in a dark wall. The door of the next exit was discernable during preliminary series from the other portions of the wall, but much less clearly than in daylight vision.

² Two + choices occurred at the end of the preceding series.

A significant change in this learning process occurred when the chick, moving in the direction of the stimulus, turned aside and approached the exit with that peculiar side-to-side-head-bobbing-and-neck-stretching behavior that is characteristic of a curious old hen. Pushing close to the exit, the chick would squat lower and lower with repeated upward bobs of the head and stretching of the neck as though in anticipation of the upward movement of the exit door. As the door opened, admitting to the relatively dark experiment box a cheerful flood of light, the chick would commonly express its satisfaction by means of the familiar hovering twitter. Where food was a rewarding motive, the hovering twitter was often replaced by a clearly distinguishable feeding twitter, and frequently the expressed satisfaction was a combination of the two types of vocalization.

From the detailed records of behavior in each individual test,³ table 15 has been computed as a measurement of the learning process in relation to the electric compartments. The table presents quantitatively the changes in the behavior of the chicks with reference to the + responses, the outside corners, the stimuli, and the inside corners. The first column merely represents the series of ten tests to which any of the quantitative measurements belong. The last column indicates the date on which the series was made. The table further presents for comparison the records of chicks 24, 25, and 27. The four columns arranged under each individual chick are arranged to show in any series (1) how many correct (+) choices were made, (2) how many times the outside corners were approached, (3) how many times the stimuli were tried as a place of possible exit, and (4) how many times the inside corners were similarly tried. For my method of collecting these data, the reader is referred to Chapter IV, pages 37 and 38.

1. If the chick profits by preceding experiences in this maze task, tendencies toward certain definite numerical limits should appear in each of the four columns presented in table 15. The number of correct choices, if there be no preference for either stimulus, should start at approximately five. Advance in the series should ultimately bring an increase in this number of correct choices which approaches ten as a limit.

³ For method of recording this behavior see page 36.

Exclusive of series 3, as reported in table 15, there is very little evidence of learning before series 10. The high record in

TABLE 15
*Measurement of Learning in terms of Correct (+) Responses, Trials at Outside Corners,
Trials at Stimuli, and Trials at Inside Corners*

SERIES	NO. 24 ♀				NO. 25 ♀				DATE
	Correct	Outside	Stimuli	Inside	Correct	Outside	Stimuli	Inside	
1	4	26	23	6	4	37	22	8	12/23-24
2	5	25	20	7	3	18	11	5	12/25
3	8	15	11	6	7	26	12	4	12/27
4	5	17	6	4	5	18	9	1	12/28
5	5	31	10	4	6	22	18	3	12/29
6	3	25	5	1	8	15	15	5	12/29
7	6	29	11	3	5	18	13	1	12/30
8	5	26	5	3	3	19	1	1	12/30
9	6	17	6	5	5	21	6	1	12/31
10	5	14	1	3	8	14	4	2	12/31
11*	6	12	2	3	3	24	0	3	1/1
12	6	22	1	3					

No. 27. ♀					Average				DATE
1	5	22	21	6	4.3	28.3*	22.6	6.66	12/23-24
2	7	25	8	6	5.0	22.6	13.0	6.00	12/25
3	9	20	9	6	8.0	20.3	10.6	5.33	12/27
4	5	19	5	3	5.0	18.0	6.6	2.66	12/28
5	7	20	6	4	6.0	24.3	11.3	3.66	12/29
6	6	19	5	1	5.6	19.6	8.3	2.33	12/29
7	7	16	6	3	6.0	21.0	10.0	2.33	12/30
8	7	18	4	2	5.0	21.0	3.3	2.00	12/30
9	4	20	5	3	5.0	19.3	5.6	3.00	12/31
10	9	11	2	4	7.3	13.0	2.3	3.00	12/31
11*	8	14	3	4	5.6	16.6	1.6	3.33	1/1
12	5	19	2	1	5.5	20.5	1.5	2.00	1/1
13	8	14	3	8					1/1
14	7	16	0	3					1/1
15	9	12	0	3					1/3
16	6	17	2	4					1/3
17	5	20	0	2					1/3
18	8	14	0	0					1/4
19	10	12	0	3					1/4
20	10	11	0	0					1/5
21	7	14	1	1					1/5
22	6	14	0	0					1/6
23	10	11	1	2					1/6
24	8	10	0	0					1/7
25	10	10	0	0					1/7
26	10	10	0	0					1/8

* Brightness reversals at beginning of series 11.

series 3 is probably due to a combination of greater relative brightness with the + stimulus for the purpose of hurrying the discrimination. Although brightness reversal was not

introduced before the beginning of series 11, it is improbable that the brightness factor served as a basis of discrimination in more than two or three series after the third. The brightness difference was rapidly reduced and in view of the brightness threshold as determined by Lashley (reference 21: Chapter 2), this factor would have been nil after series 5. The maximum number of correct choices in a series is first reached by chick 27 in series 19. Additional comment upon the appearance of discrimination evidence will be postponed for discussion in connection with the shock as a motive in the learning.

2. The number of correct choices offers a measurement of progress in forming the discrimination habit or secondary task. In the primary or maze task a more reliable unit of measurement to denote progress is the elimination of useless movements. Change in the number of trials at the outside corners offers one means of determining improvement in the experiment box. To indicate improvement, the number of trials at the outside corners must begin relatively high and decrease with ten as the minimal limit. The larger numbers in the early series may be due either to the chick's failure to step upon the proper portion of the tripping device, even though the approach is the + exit (outside corner), or to choices of the - compartment and consequent trials at the - exit.

Improvement with respect to outside corners is generally noticeable from the first. While each individual has "bad days," the table indicates a general tendency towards decrease. The average for the three chicks suggests that the curve representing the number of outside corner trials would tend to become a fairly straight line gradually descending towards the limit if a sufficiently large number of individuals were tested. This limit is reached by chick 27 for the first time in series 24 and maintained throughout three successive series.

3. Similarly, the number of trials at the stimuli must be relatively large at the beginning. As the chick learns its task, however, the unsuccessful attempts at the stimulus decrease with considerable rapidity. Chick 25 first eliminates all attempts at the stimulus in series 11. Chick 27 next reaches the same stage in series 14. It is interesting to note that perfection in this particular negative task is attained more rapidly than in the positive task of outside corner trials.

4. The remaining factor in this primary learning process is the number of approaches to the inside corner. The minimal limit denoting perfection in this task, like the preceding, is zero. This process of eliminating inside corner trials is also a negative task and perfection, again, is approached relatively early. Several of the first ten series contain only a single inside trial. Absolute perfection, however, is not reached by any chick before series 18.

The effect of the preliminary series is suggested when one compares the records of inside approaches with those of outside and stimuli approaches. The inside trials in series 1 are slightly less than one fourth the outside trials and one third the stimulus approaches. The chicks, it would seem, had acquired in the preliminary series a tendency to go to the outside rather than the inside corners. Turning to the averages, it appears that the outside corners are approached, on the whole, a greater number of times than the stimuli and the inside corners combined. This correctly indicates that the chick, in turning from an outside corner, often went to some other part of the box than my list here indicates. Often the turn was towards the rear of the experiment box followed by a return. Sometimes it was a fairly direct course from one outside corner to the other. Changes from outside corners to other parts followed failure to make an adequate adjustment to the tripping device at the first exit approach and the chicks frequently made several exit attempts before effecting the release of the exit door.

The decline in the number of stimulus approaches is the most abrupt change that appears in any of the four criteria. This is partially due to the fact that the number starts nearly as high as that for outside approaches, but the latter cannot go below ten whereas the stimulus trials have zero for a limit. The high beginning in number of stimulus trials is probably due to the fact that the stimuli are the attracting factors calling the animal to the exit end of the experiment box. Efforts directed toward the stimulus are therefore more to be expected at first than efforts at the inside corners. The most significant feature in these stimulus records, however, is the abrupt and rather permanent decreases that occur.

More suggestive, perhaps, than these numbers representing total approaches throughout a series, is a measurement based

TABLE 16
Measurement of Learning in Terms of Correct (+) Responses, First Trials at Outside Corners, First Trials at Stimuli, and First Trials at Inside Corners of Electric Compartments

SERIES	NO. 24 ♀				NO. 25 ♀			
	Correct	Outside	Stimuli	Inside	Correct	Outside	Stimuli	Inside
1	4	2	6	2	4	6	4	0
2	5	4	6	0	3	10	0	0
3	8	5	5	0	7	5	5	0
4	5	9	1	0	5	6	4	0
5	5	8	2	0	6	2	8	0
6	3	7	3	0	8	1	9	0
7	6	4	6	0	5	0	10	0
8	5	8	2	0	3	10	0	0
9	6	8	1	1	5	9	1	0
10	5	7	1	2	8	8	1	1
11	6	9	1	0	3	10	0	0
12	6	10	0	0				
No. 27. ♀					Average			
1	5	4	5	1	4.3	4.0	5.0	1.0
2	7	10	0	0	5.0	8.0	2.0	0.0
3	9	7	3	0	8.0	5.6	4.3	0.0
4	5	9	1	0	5.0	8.0	2.0	0.0
5	7	9	1	0	6.0	6.3	3.3	0.0
6	6	9	1	0	5.6	5.6	4.3	0.0
7	7	7	3	0	6.0	3.6	6.3	0.0
8	7	9	1	0	5.0	9.0	1.0	0.0
9	4	10	0	0	5.0	9.0	0.6	0.3
10	9	8	1	1	7.3	7.6	1.0	1.3
11	8	10	0	0	5.6	9.6	0.3	0.0
12	5	10	0	0	5.5	10.0	0.0	0.0
13	8	6	0	4				
14	7	9	0	1				
15	9	9	0	1				
16	6	9	0	1				
17	5	8	0	2				
18	8	10	0	0				
19	10	7	0	3				
20	10	10	0	0				
21	7	10	0	0				
22	6	10	0	0				
23	10	8	0	2				
24	10	0	0	0				
25	10	0	0	0				
26	10	0	0	0				

upon *first* approaches to these various departments. In table 16 appear measurements computed upon such a basis.

At the beginning, these *first* approaches suggest, the stimuli

and outside corners are close rivals for the majority of trials. Ignoring certain fluctuations, there is a tendency for the outside corners to gain the supremacy after the first series. At no time are the first choices of inside corners at all prominent. Some of the fluctuations which are noticeable in the table will be discussed in connection with the effects of punishment upon the learning process.

4. Relation of punishment to learning

Reflections by certain observers upon the method of punishment led me casually to note its significance in the learning process. In general, my judgment concerning the method is that it may be made most pernicious in animal training. On the other hand, it is also a valuable supplement. Whether pernicious or meritorious depends upon the intelligence with which it is applied. If the experimenter is careless in its application the results of previous training may be swept away in a flash. If he shows wisdom in its application he can certainly increase the efficiency of his technique.

My lesson on the pernicious possibilities of punishment came early with the first group of chicks. In my eagerness for results I endeavored to hurry the discrimination habit by severe⁴ and repeated shocking for wrong choices. The discrimination was easy, as subsequent results proved, but the number and severity of shocks were excessive. The result was inevitable. The most sensitive chicks became so fearful of the electric compartments that they only cowered and chirred in the rear of the discrimination chamber. Thus the subjects which continued to work were only the less sensitive animals. It was not a question of the difficultness of the discrimination problem, therefore, but a lack of intelligence in the application of the electric shock that brought disastrous results.

Subsequent observations have encouraged the belief that the value of the shock cannot be determined in terms of ease

⁴ The term "severe" should not be interpreted as "painful." The severest shock that could be administered is little more for the human hand than a tickle. The outstanding feature of the shock as a means of punishment is probably its suddenness and unexpectedness. It is very probable that a chick which chirrs, flees from the shock, and cowers in a far corner is comparable to a chick which behaves similarly when a flying hawk suddenly appears. It is not always pain, no doubt, that calls forth escape behavior.

or difficultness of discrimination, but upon the basis of an optimum dependent upon the sensitiveness of the animal. Experimental data can determine this optimal punishment within the limits of the distribution of sensitiveness in any type of animal. One should expect this optimum to vary not only with the different types of animals, but also with different individuals and at various stages of individual development and progress.

In general, the chick tends to acquire a fairly definite succession of acts in arriving at the appropriate conclusion of the series. In this series there may be a choice which involves entrance, for instance, into the left compartment. If the left compartment happens to be +, the trial at the left exit may culminate the series. If the left compartment, on the contrary, is -, the series of acts must be continued until the right exit is tried. A certain definite "set" in serial acts tends to occur, making certain errors a natural consequence.

In terms of neural organization, an integration occurs of which a portion must be disintegrated and another portion must be retained and further stamped in. That portion of the "set" which corresponds to the error must be eliminated and, if possible, without destroying the appropriate portion of the "set." Thus, the way to eliminate the error portion of the series is to shake up the "set" at the place corresponding to the error, but without shaking up the appropriate portions of the "set." A shock, then, just severe enough to have only an immediate effect is the desirable degree of punishment. Its effect should not spread beyond the error portion of the neural organization, and yet it should be efficient at that particular point. An excessive shock may uproot the entire "set" and destroy all progress that previous training has fostered. The optimal punishment, then, should be just enough to disintegrate the undesired act (or acts) of the series but not enough to extend beyond that one element in the series to other valuable acts.

My method of training chicks of the early groups was merely to adopt what appeared to be a satisfactory shock (tickle) and accept the chance results it brought. With the three chicks discussed in this paper, particular attention was given to the effect of the shock. It appeared that the heavier chicks, 24 and 25, reacted more strenuously than the lightest, No. 27.

The present observations are not presented as in any way contributing to the problem of the relative merits of punishment and reward. They are presented for the sole purpose of showing that the problem can not be disposed of after the dogmatic method of some writers nor on the basis of the superficial study of certain experimenters. The problem is introduced in this connection because of its obvious relation to the learning process.

The shock, in my study, was introduced for the first time at the beginning of series 4. The coil was set at 6 and connected with a Columbia Dry Cell No. 6. The felt pad on the floor of the entrance box was water soaked and the floor of the discrimination chamber was covered with black dry cardboard. Under these conditions, my records for No. 24 in test 4 and for No. 25 in test 5 of this series contain this interpretation: "shock seemed to tickle;" for No. 27 in test 5, where there were three possibilities of shock, "no response."

The coil was now set at 5 and the floor conditions were left unchanged. Under this new arrangement, No. 27 made no perceptible response to the closing of the electric circuit.

In the beginning of series 6, the cardboard on the floor of the discrimination chamber was water soaked. Following this change, No. 27 made no obvious response in test 3; in test 4 it turned back immediately upon the administration of the shock, but there was no violent response. The choices of No. 25 were fortunate and it escaped with very little punishment in this series. No. 24 was shocked every time an approach was made into the wrong exit, the total number of shocks being ten for seven wrong choices.

The behavior of the three chicks clearly indicates that No. 27 was least sensitive to this particular shock. It now remains to note whether or not there is evidence of a correlation between the responses to shocks and the disturbances in the methods of responding to the problem; and furthermore, to determine if possible the relative effects of such disturbances.

Responses to the electric current were so slight that little or no effects in series 4 or 5 may with reason be expected. In test 6, the shock having been increased, possible effects may be noted. The number of correct choices by No. 24 suddenly drops to 3. That this change is due to a "shaking up" is suggested by radically different types of behavior appearing

in each individual test after the third. The individual records in detail cannot well be presented, but reference to them convinces me that these changes in behavior are related to the occurrence of the shock. The "shaking up" in each test where wrong choices occur clearly affects subsequent behavior.

No extraordinary results for No. 24 appear in table 5 prior to series 10 in which the number of stimuli approaches drops off abruptly. In series 9 and 10, as presented in table 6, a change appears with reference to *first* approaches to inside corners. The single *first* inside approach of series 9 occurs in test 9 following a shock for a wrong choice. My notes in this connection read:

No. 24 is becoming wary of shocks; has not reached stage, however, of No. 27. No. 24 is very sensitive; jumps and screams slightly at each punishment; continues into compartment with sudden haste and jumps when shocked. . . . No. 24 is beginning to appreciate that shock 'means something;' No. 27, in addition, seems to be coming to an understanding of *what* the shock means.

In connection with test 10, in which an error also occurs, the following observations are reported:

Approached — compartment very cautiously; entered cautiously after inspecting compartment from two points of view,—one near the partition, the other near the right side of the experiment box; stopped on receiving very brief shock (did not jump or scream); same touch of key was repeated (no jump or scream); turned out from right side; moved deliberately but continuously in a semi-circle and entered — compartment near partition; started toward left front corner (inside), but stopped 6 or 8 cm. from the beginning of the electric wires and retraced the distance entered; turned sharply around end of partition, entered + compartment, and crossed diagonally to + exit.

In series 10, No. 24 made two *first* approaches to the inside corners. One of these responses occurs in test 3 following a shock, the other in test 5 where the inside corner of the compartment was first approached but followed by a retreat, a — choice, and a shock. During the latter half of series 10, it was observed that the chick became "hasty" in making choices.

Turning now to the tabulated records of No. 25, table 5 shows for series 8 a sudden drop in the number of stimulus approaches. Here, it appears, is the point where the severity of the shock succeeded in taking the chick's attention away from the stimulus. The punishment, as that for No. 24 in series 9, tears up a "set" by commanding attention that was

formerly given to other factors. That the effects of the punishment in the training of No. 25 were too far-reaching, is indicated by the number of + responses in series 8 to 11 inclusive. Series 10 is the only one where a high percentage of correctness appears, but my notes suggest that the record is misleading. The notes on this point read: "The high + record is not confirmed by the behavior; takes either compartment hastily without trying to get a cue." The time record confirms the notes. For the series, the average time for choosing was 3.4 seconds. The maximum time in any one test was 5 seconds.

For chicks 24 and 25, therefore, the behavior indicates that the effects of the shock were too far-reaching. There occurs such a shake-up in the responses that the chicks get even further from the solution of the discrimination problem than they were several series earlier. For No. 27, on the contrary, the shaking-up does not appear to have such negative results.

For No. 27 it is difficult to point to any abrupt changes in the measurements provided by tables 15 and 16. In general there seems to have been a fairly regular development of the discrimination habit. Instead of taking suggestive numbers from the tables, therefore, I shall refer chiefly to my notes and details of behavior.

The first suggestive change in the behavior of No. 27 occurred in series 9. The following note appears in connection with test 8 in which there is an error and approximately three times as much activity recorded as in any other single test of the series:

Behavior indicates that No. 27 has become upset by punishment; it did not know what to make of the two shocks this time. For some inexplicable reason it seemed to want to go to — exit, but after shock, was wary of both compartments; frequently crowded up close but would not risk stepping in. Seems to be a new stage in learning; recognizes that danger (shock) is connected with these escape compartments. No other chick has reached this stage.

For test 9, the notes read:

Very careful; behavior bears out above suggestion regarding shock; approached electric compartment very carefully; stopped the instant the shock came, turned out, and went directly to the + exit. Suggests that shock has become a sign that 'this is wrong compartment; other one is right.'

The notes in connection with test 10 are similar:

Again confirms above notes; each movement was "deliberate;" careful looking in direction of stimuli; inspected — compartment thoroughly from two positions close to wires, one being near partition, other near outside of box: + compartment next inspected and entered very short distance; chick stopped and looked carefully again, then continued slowly but steadily to the exit where it escaped. The first evidence that No. 27, or any other chick, considers stimuli in choosing; doubtful if chick understands problem, but it is approaching a solution.

These observations occur at the end of a series in which the chick made the fewest correct choices during its entire period of training.

In series 10, chick 27 made 9 correct choices. An error occurred in test 2. A note in explanation of this error says:

See notes for series 9 (given above); confirms observations there recorded. Concerning the series, the notes read: The same carefulness and deliberation appear throughout this series. The bird has evidently discovered some factor in the last thirteen tests which enables it to respond appropriately.

In connection with series 11, it was observed:

The behavior indicates that it recognizes the stimuli, or some accompaniment, as representing a signal for choosing; the recognition, as such, however, does not imply that the "signs" are fully comprehended; the discrimination habit is started and it must now be "worn in" by repetition. The problem seems to be recognized and the chick is putting forth an effort to solve it. The chick is in a very interesting stage of learning.

An interesting comment comparing the stages of learning attained by chicks 24 and 27 appears in my notes at the close of series 11.

No. 24 seems to have reached a stage attained by No. 27 at the close of series 9. There is now a tendency to turn back after a shock instead of continuing to exit; the shock is beginning to have a definite meaning. The significance of the shock, however, is not so great for No. 24 as it was for No. 27 in the last three tests of series 9. No. 24 does *not always* turn back on receiving the shock. No. 27 has not failed to turn back promptly since test 8, series 9. This is probably due to the fact that the same intensity of shock affects No. 24 more than No. 27. The shock seems to be optimal for No. 27 but too severe for No. 24.

The low number of correct choices by No. 27 in series 12 is probably due to the introduction of new brightness conditions for control purposes. Errors occurred in tests 1 and 7-10. These new features were added only in tests 7-9. It is questionable, also, whether an error should be charged in test 10. After comparing both stimuli, the chick went to the rear right

corner of the discrimination chamber. From this point it advanced to a position close to the — compartment, and in turning, stepped upon the entrance edge of the electric wires, but stepped off immediately and went directly to the + compartment which was promptly chosen. An error recorded for test 6, series 14, is likewise questionable.

The records of No. 27 in series 12–14 were made in a single day (Saturday). The chick was allowed to rest over Sunday. On Monday, series 15–17 were completed. In connection with the 15th series it was noted that “the characteristic behavior of Saturday persisted over Sunday.” In series 16 the chick seemed to become careless prior to the last three tests, in which the choices were carefully and correctly made. Preceding shocks for wrong choices, it appeared, had encouraged greater care which, it was hoped, would continue throughout series 17. During the first five tests carefulness did continue and the responses were correct except in test 1. But during the last half of the series, four wrong choices occurred.

In series 17, the chick began for the first time to make the feeding-hovering twitter during the choosing period prior to its entrance into the electric compartment.

5. Summary

Natively, No. 27 was found to differ from chicks 24 and 25 in manifesting a persistent side preference and in responding more slowly. Throughout the first three training series, No. 27 maintains an average time for + choices practically equal to that of the other chicks. In series 2 and 3, the — choices of No. 27 are notably low and the average time involved when these errors occur is much higher than that for the other chicks. On the whole, it seems that in No. 27 there was a relatively high persistence combined with a relatively low variability. These characteristics seemed to remain at a fairly constant level throughout the period of experimentation. Alternation between moderate persistence and high variability was characteristic of chicks 24 and 25. The former type of behavior probably predominated in No. 24, the latter in No. 25. Under the conditions of this experiment, No. 27 was the most teachable subject, although in certain phases of the tasks presented it did not always excel.

The maze habit was found to be measurable with reference to approaches to (1) outside corners, (2) inside corners, and (3) stimuli. Measurability of the discrimination habit was based chiefly upon + and - choices, but certain qualitative criteria were found to be highly suggestive of stages of learning.

The method of punishment for wrong choices was found to be both valuable and pernicious. If intelligently used, it seems, on theoretical grounds at least, to be highly valuable; if carelessly applied, punishment can radically interfere with learning. It is my conclusion, although the present study does not prove it, that the optimal shock is dependent more upon the sensitiveness of the animal than upon the ease or difficulty of discrimination.

For adequate descriptions of animal behavior in problems of discrimination, these results indicate that finer criteria than right and wrong records should be seriously considered. Detailed analysis of the behavior of No. 27 reveals, at least in one place, evidence of discrimination that is not apparent from gross records of right or wrong choices. Furthermore, the common practice of presenting to many or to all subjects precisely identical experimental conditions should be critically considered. Evidently there is an optimal degree of punishment, for example, which varies with individuals. It is desirable at least that mass results be checked with intensive individual observations.

CHAPTER IX

IDEATIONAL BEHAVIOR

The question whether the chick can react on the general basis of triangularity-circularity, largeness-smallness, or rapidity-slowness was suggested primarily by the different positions regarding ideation taken by Thorndike and Cole. Their divergent conclusions concerning the evidence of ideas furnished by infra-human behavior have stimulated considerable subsequent work. The possibility of my study furnishing data for this problem is suggested in the question: does the chick discriminate on the basis of specific stimuli, or on the basis of relative stimulus difference?

Aside from its ideational bearing, this question has considerable significance also for infra-human threshold experimentation. If it be found possible to train an animal consistently to choose on the basis of relative stimulus difference, it would seem desirable to present, interspersed with the training stimulus setting, other pairs of stimuli differing proportionately by greater and less amounts both above and below the training pair. Such a procedure would tend to distribute the effect of training more evenly through a sequence of daily series. In threshold studies it would make possible a more constant vividness, in the awareness of the subject, of the problem which is presented. In the end, the experimenter could be more certain that the failure of his subject to respond appropriately was due to the threshold limit and not to indifference to the demands of the problem.

Because the material that has been gathered on this question of relativity or specificity of chick reactions is wholly incidental to the primary tasks that have been discussed in the preceding chapters, no attempt will be made to present it in detail. The result of these incidental tests with forms has been presented in Chapter VI. The failure of the chick to respond correctly when the triangle was inverted suggests a negative answer to this question of relative form difference. Negative results are also in evidence when the size of the triangle was changed.

In similar tests on relative size difference, however, the results are more positive. These incidental tests were as easily made with sizes as with forms. After the chick had been trained to react appropriately to the $\odot 28 + - \odot 12 +$ stimuli, it was confronted, without further training, with two different circles the sizes of which bore the same relation to each other as that of the former pair. This test was made with two different pairs of circles. One pair was larger, the other smaller, than the training pair of circles, but the relative difference was a constant.

The diameters of the circles used in $\odot 28 + - \odot 12 +$ discrimination are respectively 6 and 4 cm. The standard is thus three halves of the variable. A habit having been established with the 6-4 circles, these stimuli were replaced, during five tests, with 4-3 circles; during five more tests, with 9-6 circles. Nearly all of the chicks mentioned in Chapter V were tested in this manner.

The 9 cm. circles used in the tests with the larger pair of circles was cut from black card board because regulation plates of that size were not available. The circular opening was neatly made by boring with a bit through two thin strips of board placed on each side of the card board. In the dark room human observers could hardly tell that it was a substitute. Since there was no training with this cardboard plate, the substitution could have had no influence.

Not all chicks responded similarly to these novel size relations, but evidently those which were best trained responded most positively to the relative stimulus difference. With all of the subjects tested, the total positive reactions to the larger stimulus considerably exceeded the total choices of the smaller circle. Chick 21 responded without an error to both the 9-6 and 4-3 situations. Several other chicks responded perfectly at least to one of the novel pairs of stimuli. On the whole, the 9-6 test resulted in more correct reactions than the 4-3 test relation.

In brief, these tests with new pairs of circles having approximately proportional size differences indicate that a chick trained to choose a 6 cm. circle and to reject a 4 cm. circle can choose, without further training, the 4 cm. circle when presented

with a 3 cm. circle. Likewise, it can choose a 9 cm. circle when presented with a 6 cm. circle. In the one test, what was formerly the sign for rejection is accepted as a positive sign; in the other, what was the positive sign is rejected as the shock sign. Choices, it would thus seem, can be made on the basis of relative stimulus difference.

In the preceding paragraph, it has been said that the chick *can* choose on the basis of relative size difference. In my preliminary account (Chapter II: 2, p. 113), the statement is made that the chick *will* choose on this basis. Obviously, my earlier assertion is too loose, for all chicks did not react unmistakably in this manner. It would seem wholly safe, in view of the number that *did* respond positively, to say that the chick *can* react on the basis of size relationship. Whether it *will* so respond probably depends somewhat upon the degree of previous training.

Coburn's investigation of the crow's reactions to relative stimulus difference is hardly comparable with my work on the chicks. Before the relative difference tests were made, the crows had been trained with 5-2, 9-5, 5-3, 3-2, and 6-3 combinations. On August 25th, the size training ended with the 6-3 combination. On the following day, "relative reactions" to the 3-2 combination were tested with positive results. This was followed by 6-4 training and positive results for the 9-6 "relative reactions." Again the 6-4 training was followed by positive results for the 3-2 "relative reactions."

In comparison with the preliminary training of my chicks, the crows had received a wide variety of experience with different circle combinations before the tests for relative reactions were made. The crows had actually received training with the 3-2 combination which makes me inclined to question the propriety of Coburn's conclusion:

The results of these experiments indicate fairly clearly the relativity of the crows' reactions. . . . For example, on August 24th and 25th, when the 3 centimeter circle was presented with the 5 centimeter circle, the crow reacted to the 3 centimeter circle thirty-seven times negatively and three times positively. On August 26, the 3 centimeter circle, displayed with the 2 centimeter circle, was reacted to positively in every case.

Coburn seems to overlook the fact that this same crow had been specifically trained on the 3-2 relation from August 12th to 17th.

Furthermore, Coburn's 9-6 relative reaction tests had been closely approximated in training when the 9-5 combination had been employed. For this reason his additional comment again seems questionable: "The results for crow No. 1 with the 6 centimeter circle when displayed with the 4 centimeter and the 9 centimeter circles, on August 26th and 27th were almost as decisive." While there had been no specific training on the 9-6 combination as such, there had been, aside from its close ap-

TABLE 17
Reactions to Relative Flicker Difference
Chick 27 ♀

DATE	STIMULI	NUMBER OF TESTS	NUMBER CORRECT	CONTROL SERIES 7
1/12	40'' - 20'' (50 flashes)	5	5	
	20 - 10 " "	1	1	1 (faster)
	40 - 20 " "	5	5	
	80 - 40 " "	1	1	1 (slower)
1/13	40 - 20 " "	5	5	
	80 - 40 " "	1	0	2 (slower)
	40 - 20 " "	5	4	
	20 - 10 " "	1	0	2 (faster)
1/14	40 - 20 " "	5	4	
	80 - 40 " "	1	0	3 (slower)
	40 - 20 " "	5	5	
	20 - 10 " "	1	0	3 (faster)
1/15	40 - 20 " "	5	4	
	20 - 10 " "	1	0	4 (faster)
	40 - 20 " "	5	5	
	80 - 40 " "	1	1	4 (slower)
	20 - 10 " "	1	1	5 (faster)
	80 - 40 " "	1	1	5 (slower)

proximation, frequent changes from one relation to another which might have had the effect of a "relative difference preparation." It seems probable that Coburn's conclusions are correct but they are hardly justified on the basis of his experimental method alone.

My results on the reactions of the chick to relative rates of flicker are less positive than the results from the size tests. The method in the flicker study was slightly changed. As table 17 indicates, the chick's training was continued daily while two relativity tests were inserted in each series consisting both of faster and slower rates of flashing. The first day the chick chose the slower rate regularly in all training tests and in both of the relative flicker tests. On the second and third days

it responded negatively in both of the relative stimulus tests. On the fourth day, four of the relative reaction tests were made, of which three were correct. The final result for these special tests was five correct and five wrong reactions. In the faster relative combination, there were only two correct choices; in the slower, there were three positive responses out of five. In each of the first relative flicker tests the responses were correct.

The results of the tests on the relativity of the chick's choices is thus different for each of three kinds of stimuli. With forms, it was so difficult to train subjects that the results are rather meager, but as far as they go they seem to be negative. With sizes the results are fairly positive. With flicker perception, again, the data are too meager to warrant a conclusion on the relativity problem. In general, it seems that with certain stimuli the chick *can* respond on the basis of relative stimulus difference.

CHAPTER X

GENERAL CONCLUSIONS AND SUMMARY

The results of the preceding study can leave no doubt as to the relative importance of size and form in the chick's visual life. It has been found that the number of tests necessary for the formation of a discrimination habit is much greater for forms than for sizes. Moreover, there was little difficulty in finding chicks that could readily discriminate sizes, but subjects that could discriminate forms, even after long training, seemed to be less plentiful. This study has also revealed the fact that even after perfect reactions to the circle-triangle are established, the form element as such plays no part in the discrimination.

The relative discriminative value of size and form was further tested by removing from the visual complex all but one of these factors and comparing the effect of different eliminations upon the chick's choice. The remainder of the complex, exclusive of size and form, was treated as a single factor and is spoken of as "brightness and general illumination." In table 18 the result of this special test is summarized from the records of chicks 15, 16, 17, 18, 19, 20, and 21. The averages of this table indicate that size was first in importance. Correct choices (R) on the basis of size difference alone, series 14, are 86 per cent of the total chances. The complex remainder called "brightness and general illumination" stands next, series 15, with nearly 70 per cent of correct choices. The average record is lowest when form provided the only discriminable basis, series 12, with correct and wrong choices nearly equal. It thus appears that the relative value of special factors in the chick's vision, arranged in the order of their importance, are size, the complex of brightness and general illumination, and form.

No certain comparison between the rôle of flicker and that of size and form can be made on the basis of the present study. However, on the strength of casual observation, it appears

pages, it is quite probable that the reactions observed were made, not to the visual details which the experimenters sought to present to the chick, but to unsuspected visual complexes similar to the "complex remainder" which is here designated as "brightness and general illumination." It is desirable that subsequent studies further analyze our visual complex and determine the visual acuity of the chick with each element as has been done with size and form.

When presented with a standard circle 6 cm. in diameter, it has been found that a variable circle 4.5 cm. in diameter can be discriminated by the chick. If one were to increase the size of the variable by increments no greater than one millimeter, it is probable that the chick would be able to discriminate a larger variable than the 4.5 cm. circle. The threshold of difference with a standard 6 cm. circle, therefore, is certainly one-fourth and perhaps less. In the perception of size the ability of the chick is evidently inferior to that of the crow.

Earlier experiments on the chick's perception of forms have failed to eliminate all discriminable possibilities other than the factor of form. The chick can discriminate between circles and triangles and circles and squares which are equal in area, but, with the conditions as described in this study, none of the subjects were able to discriminate between visual stimuli on the basis of form alone. Reactions to visual stimuli which have been interpreted by observers as indicating form discrimination have probably been made on the basis of unequal stimulation of different parts of the retina. If local inequality of excitations be the basis of these reactions, then the apparent discrimination of form by the chick is, in reality, a keen perception of size differences. In the perception of form, also, the ability of the crow seems to surpass the ability of the chick.

The chick evidently has a keener perception of flicker than of form stimuli. The present experiment indicates that it perceives at least a two to one flicker relation. How much lower the threshold may be, this study has not indicated.

The discrimination method employed in the present investigation furnishes a means of recording the learning process of the chick. An essential part of the discrimination habit is a maze problem. The formation of this maze habit, it was found, can be quantitatively measured in terms of approaches

to outside and inside corners and to stimuli. The most reliable measurement of the discrimination habit itself is the number of correct choices. In addition to these quantitative measurements, certain qualitative criteria were found to be highly suggestive of stages of learning.

The method of punishment was found to be both valuable and pernicious. If intelligently used, it seems to be highly valuable; if carelessly applied, punishment can radically interfere with learning. The maximum value of punishment in chick work evidently depends upon the alertness of the experimenter in selecting an optimal punishment for each subject.

A chick can acquire a perfect circle-triangle or circle-square habit, but control tests indicate that it has no general idea of circularity in contrast with triangularity or squareness. On the other hand, a large-small trained chick can react positively to the larger of two stimuli even though this particular stimuli had been the shock sign of the training combination. Also, the positive stimulus of the training pair, when presented with a larger circle, may call forth negative reactions. Positive results on the question of relativity were not secured from the flicker experiments.

The order of importance of the visual factors which have been studied, it would seem, is size or flicker, the brightness and general illumination complex, and form.

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A selected bibliography on the origin and history of the domestic fowl appears on page 5. A complete bibliography of experimental work with the domestic fowl to 1916 appears on page 20.

VITA

Harold Clyde Bingham was born January 21, 1888, near Rowan, Iowa. He received his elementary education at home and in the public schools of his native state after which he attended the high school at Rowan and the preparatory school of Ellsworth College at Iowa Falls, Iowa. He received the degree of A.B. at Ellsworth in 1910 and A.M. at Harvard in 1912. He was a student in the Graduate School of Arts and Sciences at Harvard University through the academic years 1910-1912 and 1915-1916, during which time he was assistant in psychology. In his last year at Harvard he was allowed by special vote to hold at the same time an Austin Scholarship and an assistantship in psychology. During the current year he has pursued further graduate work at the Johns Hopkins University.

In 1916 he was elected to membership in the American Psychological Association and in 1920 he became a member of the Cosmos Club of Washington, D. C. He is also a member of the American Association for the Advancement of Science.

In 1907-1908 he was superintendent of Schools at Rowan, Iowa. From 1912 to 1920 he held a professorship of Education and Psychology at Ellsworth College from which he was absent on leave during the last three years for service in the United States Army. As a first lieutenant he was assigned to Psychological duty in the Medical Department of the Army. He was promoted in 1918 to the grade of captain and designated Chief Psychological Examiner with station at Camp McArthur, Texas. During 1919-1920 he was placed in charge of the Section of Psychology in the office of the Surgeon General of the army. Immediately following his appointment as Chief of the Section of Psychology he was promoted to the grade of major. With his discharge from military duty in 1920 he accepted an appointment as Scientific Associate at the National Research Council.

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